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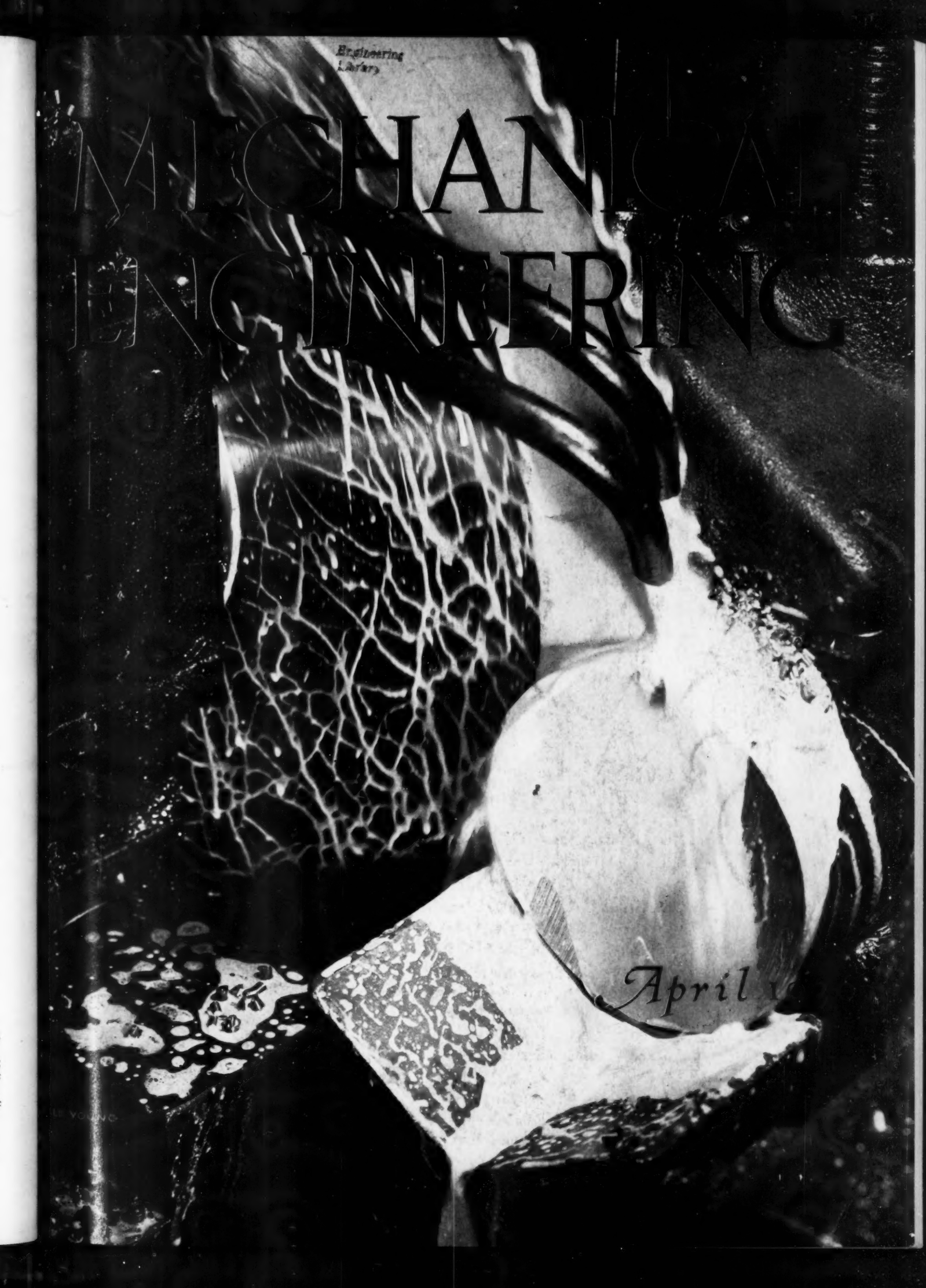
MECHANICAL ENGINEERING



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FLYING AT AN ALTITUDE OF 16,000 FEET THROUGH UPSILLATA PASS FROM SANTIAGO, CHILI, TO BUENOS AIRES. IN THE BACKGROUND IS MT. ACONCAGUA, THE HIGHEST MOUNTAIN IN THE WESTERN HEMISPHERE, 23,098 FEET
(This picture was taken from a Ford Tri-Motor from which the photographer controlled the position of the Douglass by radio.)

VOLUME 58
No. 4

MECHANICAL ENGINEERING

APRIL
1936

GEORGE A. STETSON, *Editor*

4000 Student Members

THERE are enrolled as student members of The American Society of Mechanical Engineers slightly less than 4000 undergraduates of the 115 engineering schools in which the Society has established student branches. Members of the Society, not personally in contact with this branch of its activity, are amazed at this number, which is between a third and a quarter of the total number of members of other grades. It signifies that there is plenty of potential life blood for the Society.

In his recent trip of 4000 miles throughout the Southern and Southeastern states, President Batt addressed 15 of these student branches, and returned with a most enthusiastic report of the interests and activities he found among them. Remembering that it was in this region that the revised plan of student-branch affiliation was first put into effect, it is heartening to have this testimony of the successful operation of the plan and the good fruits it is bearing.

Employment of Recent Graduates

MENTION of 4000 members in the student branches of The American Society of Mechanical Engineers will raise the question in the minds of some as to whether there will be jobs enough for these young men. The good old days of easily found jobs for college graduates may not have returned, but recent graduates are not going about unemployed.

Statistics covering graduates of the Stevens Institute of Technology since 1930, as of March, 1936, quoted by Harvey N. Davis, president of the Institute, showed that of the 539 graduates of the six classes, 18 were unemployed, say slightly more than 3 per cent. Without arguing that this is typical of the whole country, it does controvert the pessimistic view expressed by many that there are no opportunities for engineering graduates. It also indicates that as times grow better opportunities will be abundant.

By Any Other Name

IT IS amazing to find that principles as old as man himself can create excitement in modern times by blossoming forth under a mysterious new name—Stakhanovism. Stakhanovism comes out of Russia where it is said to be regarded as a mile post of economic development. Its methods of work "lay the foundation for a new era during which the aim will be the establishment of 'maximums' and the attainment of a 'full life' for the individual." Putting it simply, Stakhanovism appears to be a method of well-directed work that will result in maximum production and efficiency.

There is certainly nothing new in the application of intelligent common sense to the doing of work, no matter what name it may go under—industrial management, Taylorism, rationalization, or Stakhanovism. Laziness, incompetence, sabotage, and soldiering—even zeal when it bungles—have no place in any worthwhile group of workers. What distinguishes the management movement under its new name of Stakhanovism is not its method, or its objectives, or its alleged success, but the manner in which it is said to have been received. One enthusiastic expounder of the movement comments that it has been difficult to find engineers and administrators able to direct and integrate it.

Engineers in this country recall the difficulties that are generally encountered when methods of management are reorganized, particularly if they are obviously intended to increase production of the individual workman. The representatives of labor have missed many a fine bet by trying, from time to time, to stand in the way of inevitable changes in production methods. Engineers and administrators have had to face opposition in introducing better methods and greater production. If the tables *are* reversed in Russia, the enthusiasm of workers and the incompetence and inexperience of management would offer an explanation.

Fifty Years of Alternating Current

FIFTY years ago, on March 20, 1886, William Stanley, Jr., established the first alternating-current system of electrical distribution in America. Viewed with our familiarity of a nation-wide network of high-tension transmission lines bearing alternating current, it is hard to understand that such a system had to have a beginning, and had to fight its way into almost universal use against imposing obstacles.

The use of direct current had been well established in this country in 1886, and was much more easily transmitted than any of the mechanical forms of energy in use up to that time. But when it came to such developments as those at Niagara, where attempts were to be made not only to use the electrical energy at the source

but also to transmit it for use at a distance, the practicability of alternating-current transmission became an important factor. Stanley's transformer supplied the means for combining the advantages of high voltage for transmission and low voltage for generation and use. As it has been developed, it has removed a major portion of the handicap of distance in electrical transmission. It has made accessible remote sources of power, it has permitted the economic location of power plants with respect to condensing water and market, and it has made it possible for rural inhabitants of outlying districts to secure the benefits of electricity that would otherwise be denied them.

A Perfect Safety Record

AN INTERESTING comment by Commander Rosendahl on our airship editorial of last month brings out a point that needs emphasis. Overcautiousness, born of an ignorance of the true facts, led us to say that the record of the smaller, nonrigid type of airship, as compared with that of the larger ships that had met with disaster, "has not been so uniformly bad." This decidedly negative compliment, it seems, deserves more positive statement, and we have Commander Rosendahl's word for it that "the record for passenger transportation by small nonrigids in this country on a commercial basis, has been perfect."

Without a scratch to a single person, the Goodyear fleet of "blimps" has carried a total of nearly 200,000 passengers. In fact, commercial lighter-than-air ships are the only means of transportation having a perfect passenger safety record. This includes the early German commercial effort, the *Graf Zeppelin*, and the Goodyear "blimps." From this record Commander Rosendahl derives the basis for saying that casualties in airship operation have occurred to military and naval efforts "where there certainly has not been the continuity of effort that the Germans have displayed in their airship program."

If the Navy reenters the lighter-than-aircraft field on the basis of the report of the advisory board noted last month, and heeds the principles laid down by the board, future experience with this type of ship should provide as perfect a record as has been established in commercial service.

Discussion of A.S.M.E. Papers

AT A RECENT meeting of the Committee on Publications of The American Society of Mechanical Engineers consideration was given to the rigid adherence to closing dates on discussions of A.S.M.E. Transactions papers. These dates, announced in a footnote to every paper at the time of publication, allow two months for the preparation of discussion by readers. In considering a longer interval, it was thought that the Committee's duty to readers demanded publication of discussion as soon as is practicable after publication of the paper. Hence the two-month interval was adhered to, and the rule reasserted that discussions received after closing dates shall be returned to their writers.

Lest this rule seem too arbitrary, the following exposition of procedure is offered in explanation. Discussion of A.S.M.E. Transactions papers comes from two sources; those presented at the time the paper is delivered at a public meeting, and those written by readers who see the paper for the first time in its printed form but have not entered the discussion at the meeting. No stenographic report is made of A.S.M.E. meetings, and those who discuss papers must accept the responsibility of sending a typescript of their discussion to the secretary, or leave it with the recorder at the meeting, as no effort is made by the staff to round up discussion by correspondence.

As discussions are received at headquarters they are acknowledged and filed. When the closing date arrives, all discussion is edited by the staff and put into type. Each discusser then gets a proof which he is to correct and return. Failure to return the proof within the allotted time (approximately two weeks) is presumptive evidence that no changes or corrections are desired.

With all corrections incorporated, the complete discussion in printed form is sent to the author, with a request that he prepare a closure. Should the author delay, a follow-up system reminds him of this fact, but should he continue to fail to prepare his reply, the discussion is printed without it. Closure and corrected discussion are then returned to the printer, and finally assembled in page form for publication. Printing in the earliest possible issue of the Transactions then follows.

It is obvious with the number of persons involved in the discussion of an average paper that, even with the greatest promptness and cooperation, several months must elapse between publication of the paper and the discussion. Four months is a minimum, and any delay in the procedure extends this by one-month increments. Obviously, a discussion received after the closing date causes unpredictable delay, and would, in some cases, require the rewriting of a closure and the remaking of printed pages.

While the Committee wishes to afford opportunity to all readers to discuss any paper, in the interests of orderly procedure and prompt service to the great number of readers it feels that its position in adhering rigorously to the rule is justified.

It is unfortunate that limited funds do not permit the reprinting of the corrected paper with its discussion and the author's closure thereto, but at present they do not. Under the present system the paper itself is published as soon as possible, usually in advance of presentation at a meeting, and hence 14,000 readers have the benefit of the timeliness advantage so provided. Adherence to the closing dates for discussion and prompt attention to reading of proof and preparation of the closure reduce as much as possible the interval that must elapse between publication of the paper and the discussion. This explanation is offered in the interests of close cooperation of all persons involved for the benefit of readers.

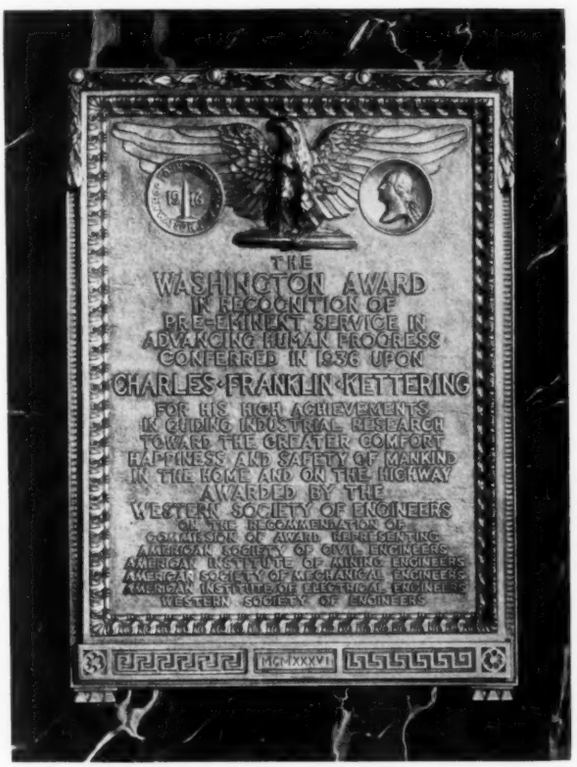
RESEARCH *and* SOCIAL PROGRESS

An Optimistic View of the Future of Engineering for Those Who Face Their Opportunities Rightly

By CHARLES F. KETTERING

THERE is a great difference between "planning" and "research." To plan beyond our ability to do may or may not be right; but if the planning is of the right order of thought, even though it may not be obtainable at the present time, a constructive research upon the subject may, and probably will, bring about the result.

Most people think of scientific research as being something to reduce the man-hours required to perform any given task. I do not know how this idea has gotten into our thinking. All the time we hear the subject of technological development talked about as something that is negative. Only in the last phases of technological development does this question of man-hours economics become important. We have forgotten entirely the other important factor—many times more important—the development of jobs and new industries.



Engineers have been blamed very largely for our present depression. We are told by reliable statistics that something like forty billion dollars lie idle in American banks. We are also told that somewhere between five and fifteen million people are out of employment. There is a human unemployment problem and there is also a financial unemployment problem. Now, the reason for this is that both of these problems are ends of the same stick. If we had new products, new projects, new reconstructive types of industry, our money and our people would be employed.

IS SCIENTIFIC DEVELOPMENT AHEAD OF SOCIAL DEVELOPMENT?

A great many persons think engineering and scientific development has gotten ahead of our social absorption ability. I wish that we would look at it in a different way. I am reminded of a man who came to a railroad station in great haste to get to a destination. The train was due to leave at eleven o'clock, but he found to his great consternation that it had left at ten o'clock. He sued the railroad company because he said the train had pulled out an hour ahead of time. At the trial the railroad company testified that the train did not pull out ahead of time, because it was the train of the day before and was twenty-three hours late.

I think that may be the reason we think engineering is ahead of its time; it is really a lap behind.

A new industry does not come full blown as a completed entity. In fact, I doubt whether anybody is ever conscious of creating an industry at the time it is started. Certainly, Oersted did not know he was creating an industry when he held an electric wire over a compass needle and found that it was deflected. He had searched for that for a long time. Michael Faraday went a bit farther and wound a coil. In that simple act of winding a coil on a bar of iron the fundamental principle of telegraphy was developed, and Morse, taking it as a clew, succeeded in developing the early telegraph. These elementary principles and the enormous communication system that we have today in the handling of the printed telegram represent millions of dollars of expended money, hundreds of thousands of hours of work, heartaches, disappointments, and discouragements. Between the elementary principle and the finished commercial product comes the great field in which industry makes its progress.

Alexander Graham Bell, in trying to improve the telegraph, trying to facilitate the methods of sending messages, discovered the principle of the telephone, and out of that came another new industry that employs thousands of men and puts much money to work. When this industry was developed, nobody thought that what Bell had discovered represented the basic principle of a new industry, but out of it and other important developments came the principles of radio and other unthought-of and, until only a few years ago, undreamed-of things.

So, today, as we discuss the relationships of science and industry and social development, we hardly recognize that there was a time that we did not have some of these things. We hardly recognize and do not appreciate the fact that while we can send a message to the farthest point of the earth in a fourteenth of a second, it may take years before it gets from the outside of a man's head to the inside. Discussing this with a scientist I asked him how he accounted for it. He said the only way he could account for it was by the relative densities of materials.

A response on the occasion of receiving the Washington Award, Chicago, Ill., February 25, 1936. Slightly abridged.

In talking with me one day, a young man said, "I think a halt ought to be called on scientific and engineering developments, because we have gone faster than we are able socially to absorb." I happened to be sitting at his desk. I said, "Let's make a 'phony' telephone call. Let's tell the operator that you would like to speak to the clerk of one of the great hotels in London. You can tell him anything that you wish, engage a room, or give any other message. Now, how much do you have to readjust yourself in order to speak across the sea as compared with the readjustment you have to make to call a department in your own institution?"

It is not the things that we have today that are vexing us from the standpoint of social development. It is the imaginary things we think we are going to experience that we do not quite understand.

I asked this young man whether he had any trouble absorbing the improvements in medicine, whether he felt that he had socially outrun the improved ability to remove an appendix; how much development he had to do socially, mentally, or otherwise to get the benefits of the best surgeons in the world. I think it is foolish for us to say that we are not able to absorb these developments socially. What we need to do is to work out the economics of these developments so they can flow infinitely more freely than they do. We have developed many things today which should have a wider distribution, and I do not know whether it is up to the engineer to work out the economics and the method of distribution or whether that belongs to the so-called economists.

In every industry and in every age we have always wished for things—things that we did not have. In engineering, as we all know, we have had the idea of perpetual motion. We have thought of taking power from the air. We have had the idea of having a machine which, once started, would keep running forever with nothing put into it, and from which we could take out any amount of power we wanted. The idea of perpetual motion is as old as thinking man, but it is only recently that that particular type of thought has been applied to economics.

A great deal of our fantastic thinking is nothing but the same old idea of economic perpetual motion. If it works, it is wonderful; if it does not, then we will have to do as we have always done, work.

PLENTY OF POSSIBILITIES AHEAD FOR THOSE WHO ARE ABLE TO THINK

The possibilities ahead for engineers depend entirely upon their ability to think, because we know so little basically, so little of the fundamentals of engineering principles. Sometimes, I believe, we fool ourselves by saying that we know a great deal scientifically. We do know how to operate some of the factors to our benefit. We have been able, especially in sanitation and in medicine, to improve human welfare and living conditions tremendously. In many of the mechanical arts we have been able to do many things which people want done. I think the best way to evaluate those things is to try to turn time backward; in other words, imagine what we would do if we did not have this or that.

We have forgotten, for example, that in 25 years the enormous development of the motor car as a leader in industry has produced an almost complete change in our method of living. It is not the automobile from a manufacturing standpoint alone that is represented by that industry. Some thirty-odd years ago I had a canvass made of the number of people employed in the motor-car industry. The best figure I could get was about one thousand people. The best figure that we have today shows that there are about 11,000,000 people directly or indirectly sustained by that industry. The motor-car industry comprises everything that goes with it. It includes the highway, and the products of the chemists. A large percentage of the steel, enormous percentages of glass, still larger percentages of the rubber and an extremely large percentage of petroleum products go into the motor-car industry. No one thought, when making the old one-lung automobile, that he was developing not only a fundamental leader in industry, but also an accessory industry for every one of those then existent. We cannot tell what an idea is going to be. We cannot tell where its future is going to lead. We can only make the contribution of the principle and if it serves a purpose, then an industry develops. Industry grows like corn. We plant the seed and wait until the development comes. If the industry is small, it grows in a short time. If it is a great industry, it takes a long time. The great developments of the electric-lighting and telephone industries came in the second 25 years of their existence. And so, with these great industries still incomplete, we have no idea what is before us, but as long as we recognize that we do not know much about them, as long as we recognize that there is human demand for many things which you and I cannot imagine, we ought to have faith enough in our ability and in our natural disposition to great accomplishment to go ahead.

I do not feel that anybody should be discouraged because out of all of these experiences it is impossible to project industrial developments a few years ahead. I have been associated with the motor-car industry for many years and as yet I have never known even the best forecaster to be able to tell what was two years ahead. People ask, "What are the next great industries?" We cannot tell what they are because we do not know when an industry is starting. We cannot tell what is going to come because as long as certain factors are not present the industry does not develop. The radio, with its principles developed far in advance of the present vacuum tubes, became an industry almost overnight. In the technical study made by the amateurs who sat up all night to try to telegraph across the street there were developed the technicians who became service men. Radio became an operating facility rapidly because of the ready availability of trained men who had been the amateurs. They were self-educated. Why did they want to study radio? Because they wanted to go into business? No, they had no idea it was a business. It was something they wanted to do. It was an adventure. It was a pioneering effort. What did they expect to get out of it? They had no idea. It was something that needed to be done and they wanted to do it.

ENGINEERS MUST TEACH FINANCIAL SUPPORTERS HOW TO REAR INDUSTRIAL CHILDREN

In the last few decades we have become too expert in bookkeeping. We think of return on capital; and yet not every motive of life is determined by return on capital. When you buy a dining-room table do you try to figure out what its earning will be—what return you get on your invested capital? When you send your boy or girl to school do you try to figure a net return on that investment? I sometimes think that if we tried to raise human children on the basis of the highly organized bookkeeping system which we apply to industrial children, a baby nine months old would have to earn its own living.

The engineer must do one great thing. He must teach his financial supporters how to raise industrial children. Many of our advances came as the natural flux of picking up this thing or that and turning it into a useful tool. But as time has gone on, the technicalities of this development work have become greater. Today, the individual does not count for much unless

he can analyze the controlling problem and bring together groups of technicians necessary to solve it. We are in a transition from the individual to the group as the producer of new industries. We do not know how to do group work very well.

We must get away from the early development of a new industry on the basis of profit and loss; the basis of return on capital. We must think of it as the development of something in which faith, in which the rightness of the thing, becomes the important factor. We have detailed accounting in industry. Sometimes that same accounting is applied to research and industrial development. But these cannot live under such treatment any more than we can budget the baby's bath or milk bottles.

RESEARCH AS INSURANCE

We must treat research, therefore, as an insurance policy. Whatever we pay for it we must think of on the actuarial basis; that over a given period of time and over a fairly large number of projects enough good will come out of it to make it worth while. We say that the depression has cost us an enormous amount of money, nobody knows how much; billions of dollars, we are told. And yet a billion dollars a year would keep five or six hundred research laboratories going full time, provided we could get the men. Of course, there are not enough trained men to run so many laboratories, but if we had the men and had the laboratories running for three or four years, the banks would have no money and there would be no unemployment. We would have "help wanted" on every door of every factory in America. The price of this industrial development would be infinitely less than the cost of trying to stimulate one artificially in which the fundamental principle was not fully recognized. We cannot create unless we know our objectives. Simply to put people to work without having any recurring coordination means that when the money is exhausted there is nothing that will go on under its own power.

It is up to the engineer to advise; and in this respect I think he is to blame because he has not been as active in getting his financial advisers to recognize that the development of industry is as important as its operation. In commending this point to you, I think we all recognize that building is one of the important fields of industry. Operation is essential, but the number of people who can be employed in operation is rather small as compared with the builders. It is necessary to take our country by and large today and find out what we need, and then sit down and ask, "How long will it take us to get that? What is there about it that we do not know?"

Sometimes a great industry is held back for years because of a simple detail. If we do not recognize that detail, large sums of money can be spent and no apparent progress will be made. When, finally, that last detail is supplied, the industry snaps into action and we go ahead. Almost every line of development has opportunity. If we analyze the factors that made the motor-car industry possible, we find three important factors, one, of which, and perhaps the most important, is the pneumatic tire.

The history of the development of the pneumatic tire is one of the most dramatic in all industrial development. Mr. Dunlop did not develop the tire for motor cars. His son rode to school over a piece of rough pavement on a solid-rubber-tired bicycle and he complained about it. The father, who was a veterinarian, made a wooden wheel on the edges of which he tacked a canvas loop. Inside the canvas he put a rubber tube which he inflated with a football pump. Such was the first pneumatic tire, conceived, not as a scientific invention, but to please a small boy.

If you read the discussions in the scientific papers during the years in which the pneumatic tire was making its way on racing bicycles, you will find learned reasons advanced by engineers as to why it would or would not work. No progress was made until an unknown bicycle rider, using pneumatic tires, defeated the champion. Then everybody said, "There must be something to it." In other words, Mr. Dunlop produced a working sample. I sometimes think we discuss too much and do not make enough samples. I am a great believer in all the formulas that necessarily are used in engineering, but I feel that the fact is very much better ahead of the formula than behind it.

MORE EXPERIMENTAL WORK IS NEEDED

We can argue ourselves out without samples, while if somebody who does not know nearly as much about it as we do makes an attempt, we sometimes discover that the proportionalities of our formula are not right. If we trace the history of all industry, we find that somebody did something that everybody was sure would not work. It would not work under certain conditions, but the fellow who succeeded did not work it under those conditions. He worked under slightly different conditions.

So, I am for more experimental work in science. I am for bringing out some of the intangibles of modern science to see if we cannot spin them into the threads that the engineer can weave into everyday work.

We are told by learned men that the things we do that we think are tangible are not; that they are only mental concepts. Now that may be. We may have to have a certain kind of mind in order to believe that the microphone is immaterial, or that this watch is simply a correlation of mental phenomena. There may be minds that can grasp that concept, but it is not an engineer's mind. An engineer has to have something he can hit with a hammer.

If there are some people who can conceive of these things without any material relationship whatever, I glory in their ability, but it does not help me a bit. I have got to have a hammer and a nail to put two boards together. I cannot wish them together.

We need today to lessen that great gap that has existed and is growing wider and wider every year between the so-called pure science and applied science. They are drifting apart, and for a very definite reason. The purely theoretical man does not like the hard-boiled attitude that the commercial engineer has to assume. Therefore, when he proposes some of his schemes for which he has no sample, and we try them out and they do not work, he does not like it. Therefore, he selects problems about which the commercial engineer can ask no questions. And the commercial engineer, because of his past experiences, does not want to ask him any questions. So, between technical education and the practical application a wide breach has developed.

The younger engineers have been given much more mathematics and mathematical physics than the older ones had. I have tried to find out why. There is nothing wrong in the mathematical approach to any problem. The only point I raise is that it is not the only approach. Mathematics is a tool in engineering just as a milling machine is a tool in a factory. Because a milling machine may be good does not mean that you throw out shapers and lathes and planers. I think we are making the problem of doing simple things much more difficult by trying to "mathematize" them. As a great instructor in music once said, "Technique in music means playing the simplest passages in the most difficult way."

We have developed a lot of technique in engineering and

sometimes we make a very difficult problem out of a simple one. I cannot help but think that all of the problems of nature are simple, and I think the difficulties we have are largely due to our own conception of them.

WE ARE GOING TO LIVE IN THE FUTURE

We must get in our minds the fact that in development we are going ahead—that is one thing we cannot stop. There is nothing we can do to keep the earth from turning around on its axis. There is nothing to do about the peculiar way it has of going around the sun, which makes the seasons. There is talk about leveling out production. The first thing we ought to do is to straighten out the earth's axis and cut out the seasons. That will help a lot. But we can't do much about it. So we have got to take this world just as it is. We are going to have seasons, which is great for the dressmakers and everybody else. We have got to take the things as they are and we have got to go ahead.

The other interesting thing is that all the rest of our lives is going to be lived in the future, unless we spend too much time wishing we had lived them in the past. Therefore, I would like to make that future just about as nice a place to live in as possible. If we do not carry over too much of the old, dirty past; if we begin to think of a polished, bright, glistening, and glorious future and say, "Why is it, it can't be that way?" we can solve those problems, because I believe we can make it anything we want.

There are many things that we ought to tear down and throw away. I say, we ought to rebuild this country. The bankers and economists ask, "Where are you going to get the money?" We are going to get the money in exactly the same place we got the money to build it this far. We had none to start with. We dug this building out of the ground and put it up here. It did not have to grow. It has always been here, but it was not in this particular shape.

We can convert man-hours and material into almost anything we want. At first we are afraid of what it is going to cost. The only thing we have of any value in this world is the natural resources of the country—with which we had nothing to do. They were here long before we got here. We sometimes think we created them.

We have the man-hours of intelligent, useful people, and every time we cut out a useful world of intelligent active, skilled people, there is the economic loss. Anything we do to keep materials from being converted into human utilities is an economic loss. And if materials are converted, somebody else does something else. The money is only used as the conveyer to carry it from one point to another. We have been calculating entirely too much in dollars.

The wealth of the nation is not in dollars; it is in useful material; and the positive side of economics is the movement of useful materials through the channels of trade. That must always go ahead of the return flow of money through the counting houses.

It is up to the engineer to work on the positive side. For the last ten or fifteen years, the engineers have hobnobbed too much with the bankers. The engineer is a great person to work with the banker on the question of standardization. We have had the great standardization theory that if we make everything alike, we shall have a wonderful world.

I pictured one time the marvelous day of Utopia when every engineer had standardized everything he could think of. There was a great celebration. Down the main street of the great city of Utopia there was a parade. At the end of the street was a beautiful arch of accomplishment called "Standardization." The band played, the floats went down, and the crowds cheered. We had arrived. But if, as we marched through the arch, we had turned around and looked at the other side of it—the side we forgot—we would have found that nature had placed another motto that we didn't think of: "This is the land of stagnation, cut-throat price competition, and depression." That is where standardization will always lead in the last analysis.

I have no objection to standardizing the nails that go into my shoes or the buttons on my coat, but I do object to standardizing the style. If I want a different coat, with different kinds of buttons on it, I want to get it.

There is no more use for those buttons on my sleeve than there is for a rabbit with three ears. And yet custom and style say they go there. They were put there at one time to keep long flowing cuffs out of the soup. We have economized on the amount of cloth that goes in the sleeve, but we leave the buttons. All we need to do is to recall where we came from. Research has nothing to do with throwing away what is old, but only with going back and analyzing whether the old thing may not be entirely revived in its utility by the introduction of something new.

RESEARCH DOES NOT THROW AWAY THE OLD

We sometimes think that time has not contributed much A friend of mine, who is the president of a university, brought to this country last fall a great pharmacist who gave five lectures at a medical school. He told this interesting story. He said that for 25 years a continuous research had been conducted on the medicinal plants of North Africa. He said: "After 25 years we have not yet found one thing about those plants of North Africa that we didn't already know." In long years of cut and try the very things had been developed that scientific research proved. We need to ask ourselves, why did we do it that way? There is a reason for it. So research, so far as engineering is concerned, is to go back and study why we do a thing as we do it and how can we improve it. The other way to approach the subject is to cut loose our imagination and do a little wishing.

What are some of the things we would like to have? Why can't we have them? Research is not something that goes with a laboratory. It is purely a principle and anybody can apply it. It is simply a method of trying to find out if we are satisfied with what we have, where we are, and what we are doing. Write down ten things that you do not like about your business, about yourself, or the things you are doing or working with as your problems. You may not be able to solve number one, because it may be very difficult, but you will be able to pick out another, just as you put a word in the crossword puzzle. Finally, you will be surprised to find how these things break down if you persistently work at them. Research is simply trying to step farther ahead in order to find out what we are going to do when we cannot keep on doing what we are doing now. It does not need to be done in a laboratory. Time will move on, and time will bring new things and new facilities, if we have open minds; if we know where our industry lies in relationship with things that may exist at the present time.

The next ten years will see a complete renaissance in engineering and scientific development. It is all ahead of us. In every period somebody has said: "I don't see what new there is to be done." Go out and look. Take any book on the history of industry and tear out half of the book; read up to that point and some will say that all is finished. If we can cast out the bugaboo, "Your world is finished," and replace it with "The world is begun," we shall have a marvelous place in which to live and a marvelous future ahead of us

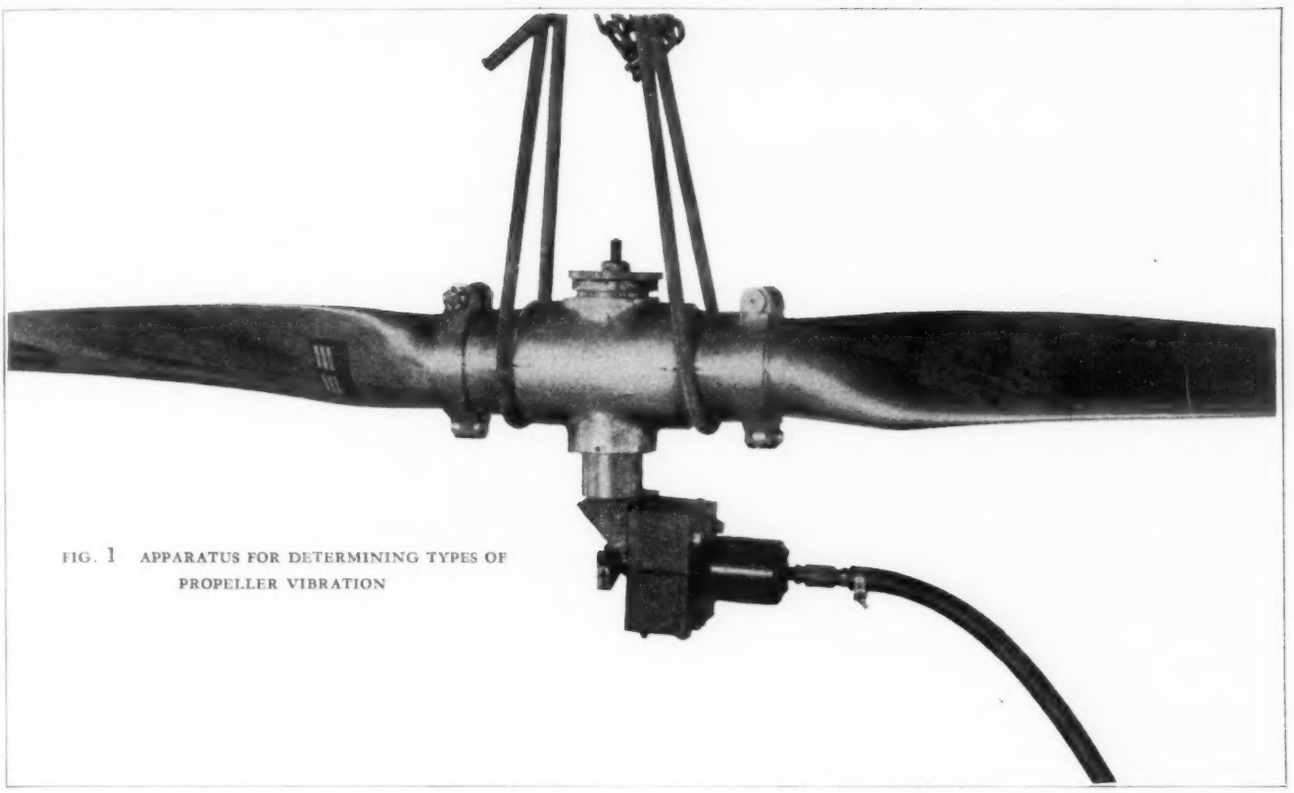


FIG. 1 APPARATUS FOR DETERMINING TYPES OF PROPELLER VIBRATION

PROPELLER CRANKSHAFT-VIBRATION PROBLEMS

By H. H. COUCH

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I—TYPICAL PROPELLER FAILURES CAUSED BY VIBRATION

A STUDY of propeller failures that have occurred in the Air Corps since 1927 has revealed the fact that practically all failures have been due to propeller vibration or crankshaft vibration, or a combination of both.

The proof that most propeller failures are due to vibration is contained in the fact that many propellers that fail on engine test will successfully pass a test on the electric motor at twice as much power where the driving torque is very smooth.

In 1933 a study to determine the types of vibration possible in aircraft propellers under static conditions was conducted by the Air Corps. The results of this study were published in Air Corps Information Circular No. 683.

METHOD OF DETERMINING TYPES OF PROPELLER VIBRATION

Only a brief description of the final method adopted as standard by the Air Corps will be given here.

Contributed by the St. Louis Section and the Aeronautic Division and presented at the National Aeronautic Meeting, St. Louis, Mo., Oct. 10–12, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

1 The blades are assembled in the hub and locked at the desired angle. If the propeller to be vibrated is of the controllable-pitch type, it is necessary to lock the blades in the hub by using shim plates.

2 The propeller is then suspended in a sling made of elastic shock-absorber cord of such elasticity that the suspended propeller will have a frequency lower than the fundamental frequency of the propeller blades. This is done to prevent energy from being dissipated through the suspension system.

3 An air motor having an eccentric weight on the rotating shaft is mounted on the front of the hub as shown in Fig. 1. Each revolution of the eccentric weight by the air motor produces one exciting impulse which is imparted to the propeller. When the frequency of the exciting force produced by the air motor corresponds with any one of the natural frequencies of the blade, violent vibration occurs in the propeller.

The speed of rotation of the air motor can be varied between 1000 and 22,000 rpm. When propeller vibration is produced, the frequency of vibration is determined by finding the speed of the rotating weight with a rotoscope.

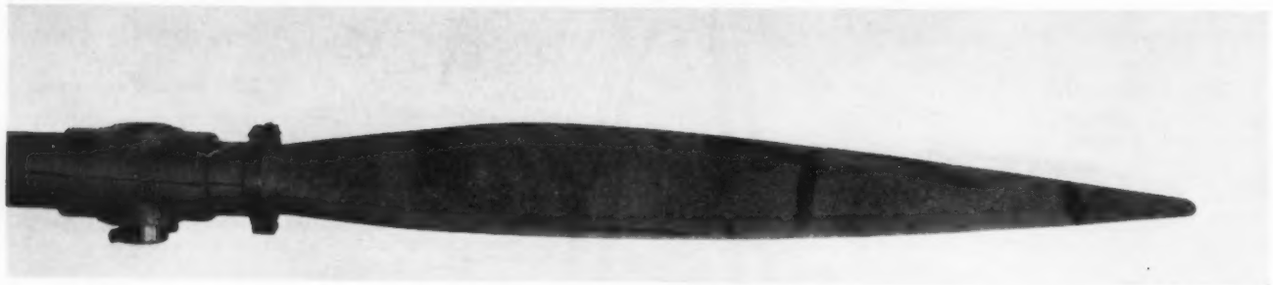

FIG. 2 PROPELLER BLADE WITH DUST PATTERN SHOWING THREE-NODE VIBRATION

BENDING TYPES OF VIBRATION

The first step in determining the type of vibration in the propeller is to shake fine wood dust on the face of the vibrating blade. The dust immediately shakes off the blades except at the nodal points, which are practically stationary. By this method it is possible to determine whether the blade has a type of vibration with one, two, three, four, or five standing nodes on each blade. Fig. 2 shows the type of dust patterns obtained for a type of vibration in which there are three nodes per blade.

The type of bending in the blade is then determined by finding the phase relation of the vibrating tips and the nature of movement of the hub. This is done by allowing the vibrating propeller to act as a circuit breaker and pass current through a neon light for a portion of each cycle of vibration.

Fig. 3*a* shows the electric circuit used, movement of the hub, and movement of blade tips for a type of vibration having one node on each blade, with a loop at the center line of the propeller hub. In two-, three-, or four-blade propellers all tips will move up and down in phase. This circuit can be used to identify all types of vibration having one, two, three, four, or five nodes per blade with a loop at the center line of the propeller hub.

Fig. 3*b* shows the electric circuit, movement of the hub, and movement of the blade tips for a type of vibration having one node on each blade with a node at the center line of the propeller hub. In a three-blade propeller the tips of two blades are up while the tip of the third blade is down. It is, therefore, necessary to hold one wire on the face side near the tip of one blade and determine the relative movement of the other two blades with respect to this one blade. In a four-blade propeller the tips of two adjacent blades are coming up while the tips of the two opposite blades are going down. This circuit is used to identify all types of vibration having one, two, three, four, or five nodes per blade with a node at the center line of the propeller hub.

TORSIONAL TYPES OF VIBRATION

In torsional types of blade vibration the blade twists about its longitudinal torsional axis. A nodal dust line appears over the center line of the propeller as shown in Fig. 4.

Large-diameter propellers may have second- and third-order torsional frequencies. These higher torsional frequencies are seldom true harmonics of the fundamental torsional frequency.

Fig. 5 shows the results of the static-vibration study on Air Corps propeller blade 32L3687. The designation 3-N indicates that there are three nodes per blade with a node at the center line of the propeller hub. The designation 3-L indicates that there are three nodes per blade with a loop at the center line of the propeller hub.

It can be seen that as the blade angle at the 42-in. station is changed with respect to the hub the frequencies of the different types of vibration also change. The frequency of the torsional type of blade vibration is least affected by blade-angle change.

ENGINE-CRANKSHAFT VIBRATION

All engine crankshafts have natural torsional frequencies that can be excited if vibrating forces of the proper frequencies are applied to the throws of the crankshaft. Some engine crankshafts have natural frequencies corresponding to the frequencies, or harmonics of the frequencies, of the engine explosions occurring within the rotational speed range used in flight. This condition imposes stresses on the crankshaft and propeller of many times the value that would be obtained if the crankshaft were running free from resonance.

TYPES OF CRANKSHAFT VIBRATION

Single-Node Crankshaft Vibration. Single-node crankshaft vibration produces a twist in the length of the crankshaft from the node to the end of the shaft. The node is located near the rear cone, usually an inch or two from the propeller. Single- and double-row radial engines have relatively short crankshafts with high natural frequencies. In some cases engine explosion excites the natural frequency of the crankshaft in the normal engine speed used in flight.

In-line engines may have a single-node type of vibration that can be excited by engine-explosion frequencies or harmonics of engine-explosion frequencies.

Two-Node Type of Crankshaft Vibration. High-speed, in-line, V-type engines having long crankshafts may have a two-node

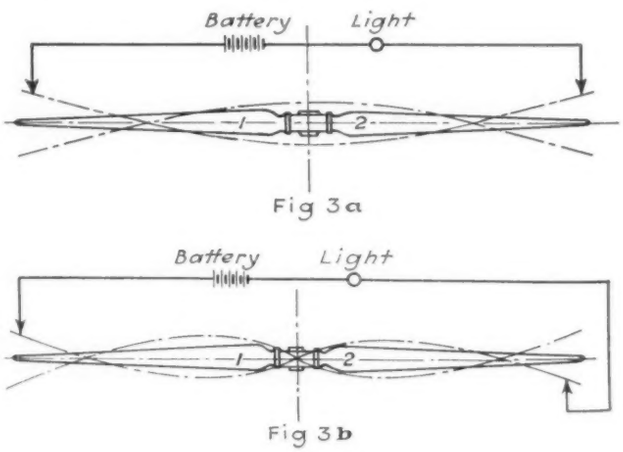

FIG. 3 METHOD OF DETERMINING WHETHER A LOOP OR A NODE EXISTS AT CENTER LINE OF PROPELLER HUB

[(*a*) Light indicates type of vibration with a loop at center line of hub. No light indicates type of vibration with a node at center line of hub. (*b*) Light indicates type of vibration with a node at center line of hub. No light indicates type of vibration with a loop at center line of hub.]

FIG. 4 PROPELLER BLADE WITH DUST PATTERN SHOWING TORSIONAL VIBRATION

type of torsional vibration. One node is located near the propeller and the other near the center main bearing. This two-node type of torsional vibration can be excited by engine-explosion frequency, or by harmonics of engine-explosion frequency. Crankshaft failures have been obtained at both nodal points during engine tests at the Matériel Division.

METHOD OF DETERMINING CRANKSHAFT VIBRATION

The Prescott torsiometer is used to determine resonant condition in engine crankshafts. This instrument measures the torsional deflection of the rear end of the crankshaft with respect to a flywheel running at a uniform speed. The instrument is described in Air Corps Information Circular No. 664. An article on this instrument was also published by the A.S.M.E.[1] Recent improvements in this instrument have been made so that records can now be made in flight by means of a remote-control system.

Service tests have shown that radial engines having a torsional twist of the rear end of the shaft of more than $^1/_2$ deg usually develop propeller or crankshaft troubles. When the torsional twist, due to resonance, reaches values of $1^1/_2$ to 2 deg the stresses in the propeller are increased to four or five times the values encountered when resonance is not present in the crankshaft.

If the twist of the rear end of a radial engine is not more than $^1/_2$ deg under resonant crankshaft conditions, the propeller will not be damaged provided the blades are free from natural frequencies corresponding to those of the resonant crankshaft.

Deflections of this magnitude of crankshaft resonance often occur at low power output obtained by reduced throttle or the operation of the engine at high altitudes where the exciting force due to engine explosions is greatly reduced.

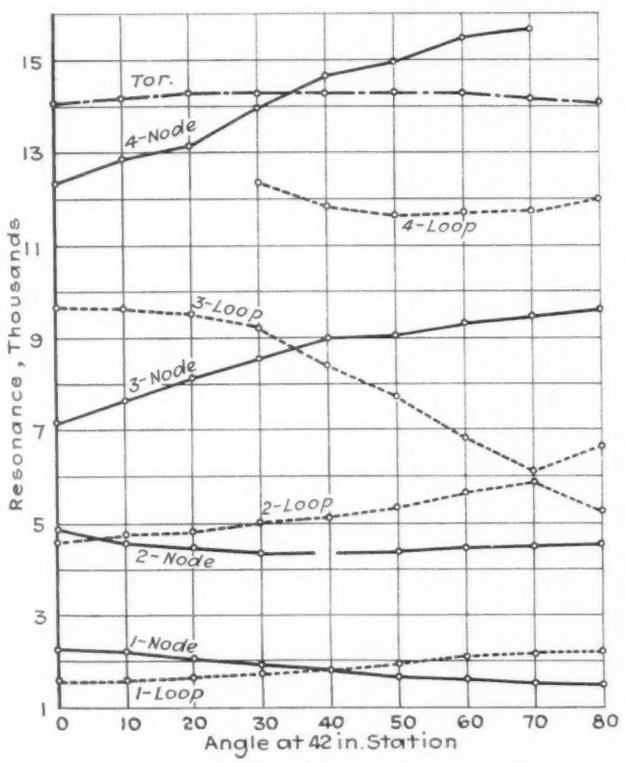

FIG. 5 RESULTS OF STATIC VIBRATION STUDY

CHANGES OF CRANKSHAFT FREQUENCY DUE TO FLEXIBILITY OF CONTROLLABLE-PITCH-PROPELLER ASSEMBLY

An investigation of the accident in which Captain Brookley was killed revealed the fact that the controllable-pitch propeller had lowered the natural resonant frequency of the crankshaft so that at 2100 rpm the propeller was operating under bad resonant crankshaft conditions. With the fixed-pitch propeller the crankshaft was not operating in resonance until the engine obtained a speed of 2300 rpm. This was above the rated speed of the engine.

Some types of controllable-pitch propellers lower the resonant crankshaft frequency more than others.

FAILURES PRODUCED BY RESONANT CRANKSHAFT VIBRATION

Resonant crankshaft vibration that occurs in the operating range of engine speed used in flight first manifests itself by galling of cones. Tests have been run at the Matériel Division where cones were badly galled and the heat-treatment of the engine shaft destroyed by operating the engine at wide-open throttle for 15 min under resonant crankshaft conditions. The horsepower output of the engine was only about 400. This same type of propeller and cone was run on the electric whirl rig for 20 hr at 1500 hp without indication of cone trouble.

Most of the cone trouble in the past can be attributed to resonant crankshaft vibration. No unsatisfactory reports have been received from engines having harmonic dampeners which eliminate severe crankshaft vibration. This is also true of flexible-spring drives which lower the resonant frequency of the crankshaft to the extent that it is out of the operating range of engine speed used in flight.

Cone troubles have also been eliminated when operating restrictions have been placed on engines preventing their operating under bad conditions of crankshaft vibration.

CRANKSHAFT, CRANKCASE, AND REDUCTION-GEAR FAILURES

If the propeller is built sufficiently strong to withstand the vibration stresses produced by bad resonant conditions in the

[1] "Vibration Characteristics of Aircraft-Engine Crankshafts," by Ford L. Prescott, Trans. A.S.M.E., vol. 52, 1930, pp. 139–152, paper AER-52-19.

crankshaft, it becomes very heavy, with the final result in the past that the trouble has been transferred to the engine, resulting in crankshaft failures, crankcase failures, and failures of reduction gearing. In some cases crankshaft resonance produces enough whip-back to wear the reverse sides of the gear teeth that would normally be free from load under operating conditions.

DAMAGE TO BEARINGS

Resonant crankshaft vibration causes brinelling of the races. Considerable galling is usually noted where the races are in contact with the blade and hub barrel.

II—PROPELLER BLADE FAILURES

FAILURES DUE TO BENDING TYPES OF VIBRATION

It has been found that all types of vibration that can be excited by use of the air motor and a rotating eccentric weight as described in the first part of this paper can be excited under operating conditions on the engine.

Failures from vibration of aluminum-alloy blades have occurred where the normal operating stresses in the blade due to centrifugal force and thrust bending moments were as low as 3000 lb per sq in. The fatigue limit of this material was 14,000 lb per sq in.

Hollow steel blades operating under resonant conditions have failed where the normal computed stresses were as low as 10,000 lb per sq in. The fatigue limit of this material was 35,000 lb per sq in.

For bending types of vibration having one, two, three, or four nodes per blade, failure usually occurs a few inches inside the node nearest the tip. Flight failures have been duplicated closely, both as to location and nature of break, by use of the air motor and the rotating eccentric weight. Failures produced by the air motor usually do not require more than five hours of continuous operation at resonance with a large eccentric weight.

Fig. 6 shows several typical failures caused by vibration. Failure No. 1 was caused by aerodynamic flutter after 15 minutes of running on the electric whirl rig. In this type of vibration the blade vibrates about its torsional axis at the natural torsional frequency of the blade. The changes in air load due to blade-angle changes at resonant frequency produces very high bending stresses in the propeller blade.

Failure No. 2 was caused by a bending type of vibration having three nodes per blade with a loop at the center line of the hub. This failure was caused by severe engine impulses that were imparted to the propeller, although the crankshaft was not actually in resonance.

No. 3 is a failure in which there were three nodes per blade with a node at the center line of the propeller hub. This type of vibration was being excited at normal cruising speed.

No. 4 was caused by a two-node type of vibration with a loop at the center line of the propeller hub coinciding with resonant crankshaft vibration. This condition occurred only at wide-open throttle on the ground and at wide-open throttle in a steep climb.

No. 5 is a test-club failure caused by the fundamental or one node per blade with a loop at the center line of the hub type of vibration that was excited by a resonant crankshaft vibration. This occurred at wide-open throttle. The fundamental frequency of the short-blade test club was very high and the resonant frequency of the in-line engine crankshaft was very low. This condition would not be encountered in a propeller of large diameter, since the fundamental frequency would be too low.

SHANK FAILURES

If the resonant frequency of the crankshaft does not coincide with any of the natural frequencies of the propeller blade, failures, due to forced bending near the point where the blade enters the propeller hub, often occur. The cause of this type of failure can be explained in the following manner: The moment of inertia of the rotating blades is very high and a flywheel effect is produced that tends to make the blades rotate at a uniform speed. When bad crankshaft resonance occurs the hub portion tends to accelerate and decelerate once during each cycle of vibration of the crankshaft, with the result that high bending stresses are produced near the shank of the blade. These stresses, added to the high centrifugal stresses in this region of the blade, often produce stresses sufficient to cause blade failure. This type of failure is the most dangerous of all, since the unbalanced centrifugal force on the remaining blades tears the engine out of the airplane.

No. 6, Fig. 6, shows a shank-type failure of a hollow steel blade produced by running at resonant crankshaft frequency for 62 hours. Both blades failed at the same station at the same time.

No. 7 shows a shank-type failure of an aluminum-alloy blade caused by bad crankshaft vibration encountered during ground operation, take-off, and climb at wide-open throttle. Luckily this failure occurred while warming up the engine for take-off. The engine was torn completely out of the airplane and the mechanic was left holding the throttle.

Fourteen cracked blade shanks were discovered on one particular propeller-engine combination. To eliminate this trouble it was necessary to install controllable-pitch propellers and place operating restrictions on the engines to prevent operation under resonant crankshaft conditions. In this particular case, as in all cases of geared engines, the heavier controllable-pitch propeller with more effective moment of inertia lowered the torsional period of the crankshaft almost below the operating range. The selection of pitch enables the pilot to operate the engine in take-off, climb, and level flight at engine speeds where crankshaft resonance does not exist.

III—STUDY OF PROPELLER VIBRATION UNDER OPERATING CONDITIONS

In the past two years the Matériel Division has experimented with several types of vibration indicators that can be used for determining the frequency, amplitude, and types of vibration while the propeller is in operation on the engine or the electric-motor test rig. To date the magnetic type of pickup described in the following paragraphs has proved to be the most successful, although work is being carried on to perfect other types before adopting any one as a standard.

The magnetic pickup consists of a permanent magnet mounted on an aluminum block and bolted to the blade. The purpose of the aluminum block is to provide a nonmagnetic support for the permanent magnet so that the device can be used for studying vibration of hollow steel and solid steel, as well as aluminum-alloy, blades. Pickup coils with soft-iron cores are also mounted on the blade as shown in Fig. 7. It can be seen that if the blade is bending, due to vibration, the magnetic gap will increase and decrease with each cycle of vibration. This produces a change of flux through the coils which generates a current in the pickup coils.

Early studies with magnetic pickup revealed two important points that must be considered if the output from two pickups is to be passed through one amplifier for the study of phase relation of different types of vibration. If the output from both pickups is not the same bad distortions of wave forms result.

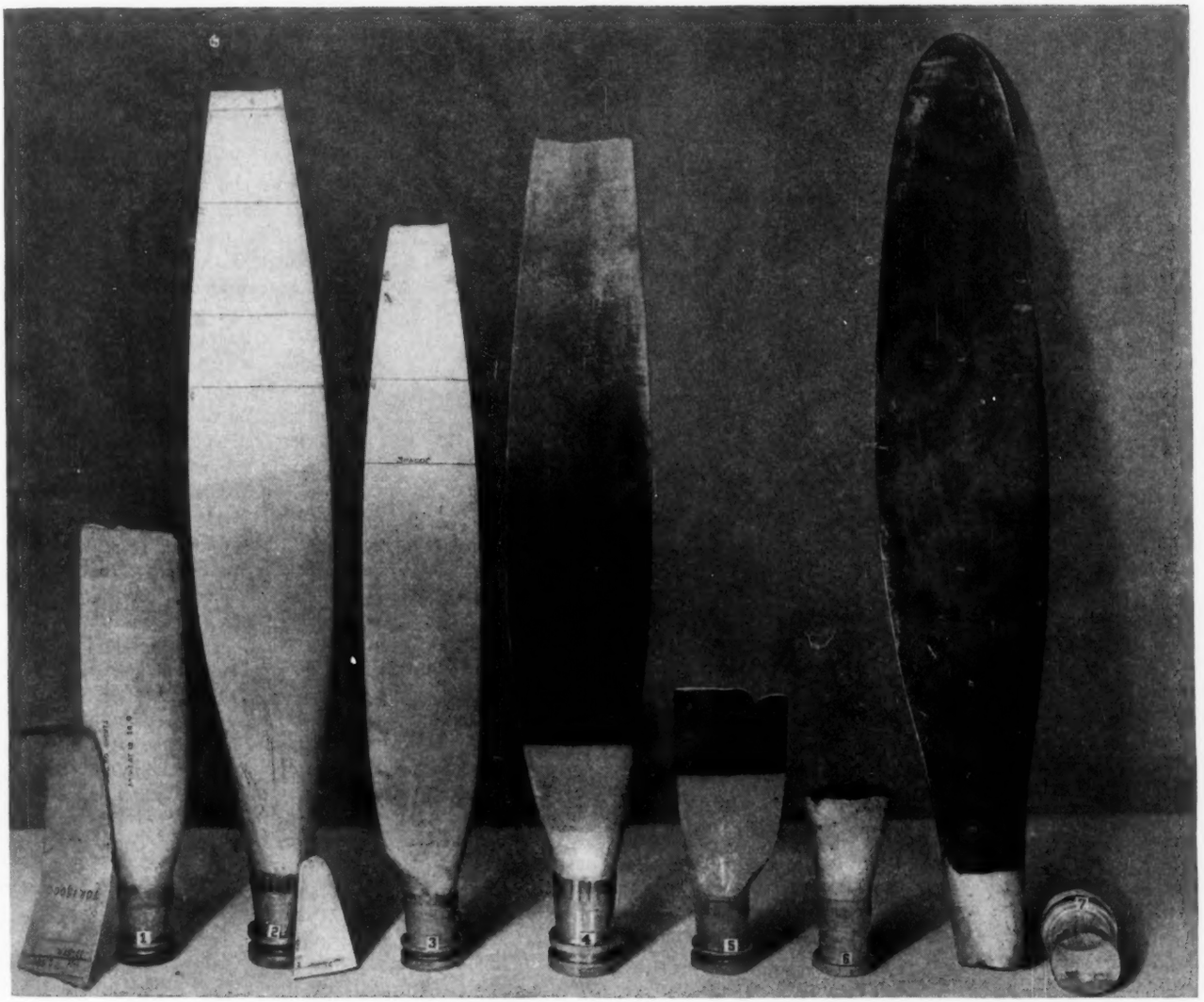

FIG. 6 TYPICAL PROPELLER-BLADE FAILURES CAUSED BY VIBRATION

(1) Both magnets must have the same strength.

To obtain magnets of the same strength it is necessary to charge the magnets to a point of saturation, place them on a blade, and vibrate them for several hours. Considerable magnetism will be lost as a result of this treatment, but the magnets will both have similar magnetic properties.

(2) The air gaps between the magnets and the soft-iron cores must be exactly the same. Even with jigs for mounting the pickups on the blades, it is almost impossible to obtain the same air gap for any two pickup installations. The pickup shown in Fig. 7, which has adjustable soft-iron cores, was designed by R. F. Conner, of the Matériel Division. Under severe conditions of propeller vibration the output from this pickup with a 0.020 air gap is between $1^1/_4$ and $1^1/_2$ volts.

MOUNTING OF MAGNETIC PICKUPS ON THE PROPELLER BLADES

The current output from the pickup coils is passed through slip rings into an amplifier and into an oscillograph where a photographic record of the current fluctuation produced by propeller vibration is made. The current may be passed from the amplifier directly into a harmonic analyzer to determine the frequency and amplitude of vibration.

The propeller is first vibrated by the air motor and eccentric rotating weight. The types of vibration are determined and the location of the nodes for the different types of vibration are painted on the blade. The pickup is then mounted on the blades at a point free from node locations. It was found that on propellers about 10 ft in diameter the pickup could be mounted anywhere between the axis of the propeller and the 24-in. station without affecting the natural frequencies of the blade.

For propellers 11 ft in diameter the pickup could be mounted out as far as the 30-in. station without affecting the resonant frequencies of the different types of vibration.

DETERMINATION OF TYPES OF VIBRATION WITH MAGNETIC PICKUPS

By referring to Fig. 3 it can be seen that when the pickups are mounted on the face of the blades the coils can be connected so that when the propeller is vibrating with any of the types of vibration with loops at the center line of the hub, the output from the coils will be additive and the vibration can be recorded and identified. When this circuit is employed, all types of vibration with nodes at the center line of the hub will generate current in the two coils that counteract each other and no record of this type of vibration will be obtained.

To determine node at the center line of the hub types of

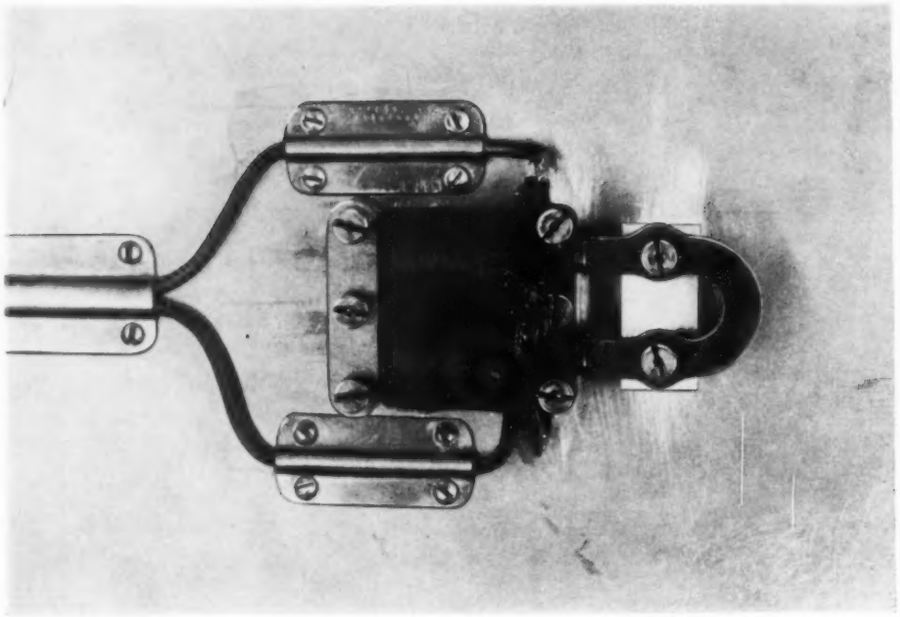

FIG. 7 PICKUP COIL MOUNTED ON PROPELLER BLADE

vibration, the coils of the pickups are connected so that the output of the two coils are additive when the propeller is vibrating with a node at the center line of the propeller hub. When this circuit is employed all types of vibration having a loop at the center line of the propeller hub will generate current in the two pickups that counteract each other and this type of vibration will not be recorded.

For the study of phase relation of three- or four-blade propellers, it will probably be necessary to use a separate pickup and amplifier for each blade and pass the output from the amplifiers into a three- or four-element oscillograph.

Vibration studies are now made by the Matériel Division on all propellers that are to be purchased for new airplanes. If oscillograph pictures show bad vibration characteristics in the range of engine speed used in flight the propellers are tested for 100 hr under the bad resonant vibration conditions.

A complete vibration study of a propeller under running conditions requires about 50 oscillograph pictures. Space permits the publication of only a few records showing resonant propeller-vibration conditions. The records were made during the test of an Air Corps propeller 10 ft in diameter on a nine-cylinder, direct-drive engine. Tests were conducted in an engine torque stand at Wright Field. The cross-sectional area of the engine compartment in the plane of rotation of the propeller was 20 by 20 ft, so that there was practically no interference between the tips of the blades and the walls of the torque stand.

DESCRIPTION OF OSCILLOGRAPH PROPELLER-VIBRATION RECORDS

The top record is produced by passing current from a circuit breaker driven by the engine through one element of the oscillograph. The contact points of the breaker open once during each revolution. Therefore, one complete engine cycle consists of two breaks of the circuit breaker.

The center record is produced by the output from the pickups mounted on the propeller blades.

The bottom record is a 60-cycle timing wave.

Oscillograph record No. 192-1, Fig. 8, shows a fundamental or (one-node-per-blade) type of vibration having a loop at the center line of the hub. This type of vibration is probably caused by the torque surge produced once during each engine revolution by the link-rod action.

Oscillograph record No. 194-1 shows a type of vibration with two nodes per blade and a loop at the center line of the hub. The exciting force in this case is probably the secondary inertia torque forces produced by the movement of the reciprocating weights.

Oscillograph record No. 194-2 shows that an increase of 42 rpm of the engine has brought the propeller out of resonant vibration and it is running comparatively smoothly. Where the exciting forces are rather small, as in this case, blade resonance does not extend over a very large range. In this particular case, resonance extends over a band of about 50 rpm of the engine.

Oscillograph record 185-3 shows a type of vibration with three nodes per blade and a node at the center line of the propeller hub. This type of vibration is probably caused by the whipping of the end of the engine shaft about a true axis of rotation because of unbalanced forces of the engine. This type of vibration may also be excited by blade passages past an object too near the propeller. In this particular case the engine supports are so far to the rear of the propeller that it is doubtful whether they could excite this type of vibration.

Oscillograph record 259-3 shows the start of a type of vibration with three nodes per blade and a loop at the center line of the propeller hub. At this engine speed the crankshaft is running under severe resonance excited by engine explosion frequency. The true resonant frequency of the propeller occurs at about 2300 rpm and is very severe. It can be seen that the bad crankshaft condition almost pulls the blade into a resonant vibrating condition at an engine speed 45 rpm below the true resonant frequency of the propeller blades.

Oscillograph record 237-2 shows a type of vibration with five nodes per blade and a loop at the center line of the propeller blade. This frequency is excited by the inertia masses of the pistons which have the effect of producing torque forces in the crankshaft, both on the compression and firing stroke of the engine.

It is interesting to note the similarity of vibration irregularities that reoccur after each engine cycle of two revolutions is made.

CONCLUSIONS

The oscillograph records reproduced in Fig. 8 show that this particular nine-cylinder radial engine does not have smooth driving characteristics. Oscillograph records taken on the electric whirl rig at the same speed and power did not have the pronounced vibration characteristics shown in the oscillograph records of Fig. 8. This accounts for the fact that propellers often withstand double engine power on the electric whirl and yet fail on engine test.

Some excellent work has been done by one of the aeronautical-engine builders in the development of a harmonic

dampener which practically eliminates resonant crankshaft vibration.

The Air Corps contemplates making a thorough study of propeller vibration under operating conditions with various types of drives. It is believed that most of the destructive forces can be prevented from reaching the propeller by the following proposed methods:

Nine-Cylinder Engines. Eliminate resonant crankshaft vibration by the use of a harmonic dampener. Reduce engine explosion impulses of nine cycles in two revolutions and the inertia impulses of 18 cycles into revolutions by the use of a flexible-spring drive. The other method would be to design a flexible-spring drive so that the resonant frequency of the crankshaft is below the range of engine speed used in flight. This drive would also reduce engine explosion impulses of nine cycles in two revolutions and inertia impulses of 18 cycles in two revolutions.

Fourteen-Cylinder Geared Engines. The vibration problem in this type of engine is not as serious as in the single-row radial or the in-line types of engines for the following reasons:

(1) The resonance of the crankshaft usually occurs in a range of engine speed below that required for flight. The exciting forces in this range are low due to low power output, and it is not likely that the crankshaft stresses will be very high even if the crankshaft is running under resonant conditions.

(2) Owing to the large number of cylinders the power overlap is sufficient to give a fairly smooth driving torque. The type of propeller vibration being watched closely on 14-cylinder engines is torsional blade vibration. The explosion frequency of the 14-cylinder engines is so high that the torsional frequency of the propeller blade can be excited. In this type of vibration the propeller blade changes angle with each engine explosion. As the angle of attack of the blade relative to the air increases, the air load on the blade increases, and the blade does a fundamental bend with each cycle of torsional vibration.

Endurance tests made under conditions of torsional blade vibration excited by engine explosion frequencies have resulted in hammering of the gear teeth on the blade end gear and some galling of the rear propeller cone.

In-Line Engines With Long Crankshafts. Engines of this type will have 12, 18, or 24 cylinders. Owing to the power overlap and the flexibility of the drive obtained with the long crankshaft and gearing, engine explosion impulses will probably not be very severe.

The one-node and two-node types of resonant crankshaft vibration should be kept out of the operating range if possible. It may be necessary to use a torsional vibration damping on this type engine, even though resonance occurs below the operating range.

It is possible to design propellers so that the natural frequencies of the blades do not correspond to the bad vibration characteristics of the engine. In some cases this requires the addition of considerable weight to the propeller blades. This has been found to be the case in designing propellers for nine-cylinder geared engines that will operate free of blade resonance between the two-node-per-blade types of vibration and the three-node-per-blade types of vibration.

The weight of the propeller can be materially reduced if a smooth driving torque can be applied to the propeller. The development of smooth drives for engines will be beneficial to both the engine and propellers, and is believed to be the most satisfactory way to solve propeller-crankshaft problems. This conclusion can only be verified by a great deal of experimental work and service testing. The solution of this problem will require the cooperation of all Government departments and engine manufacturers.

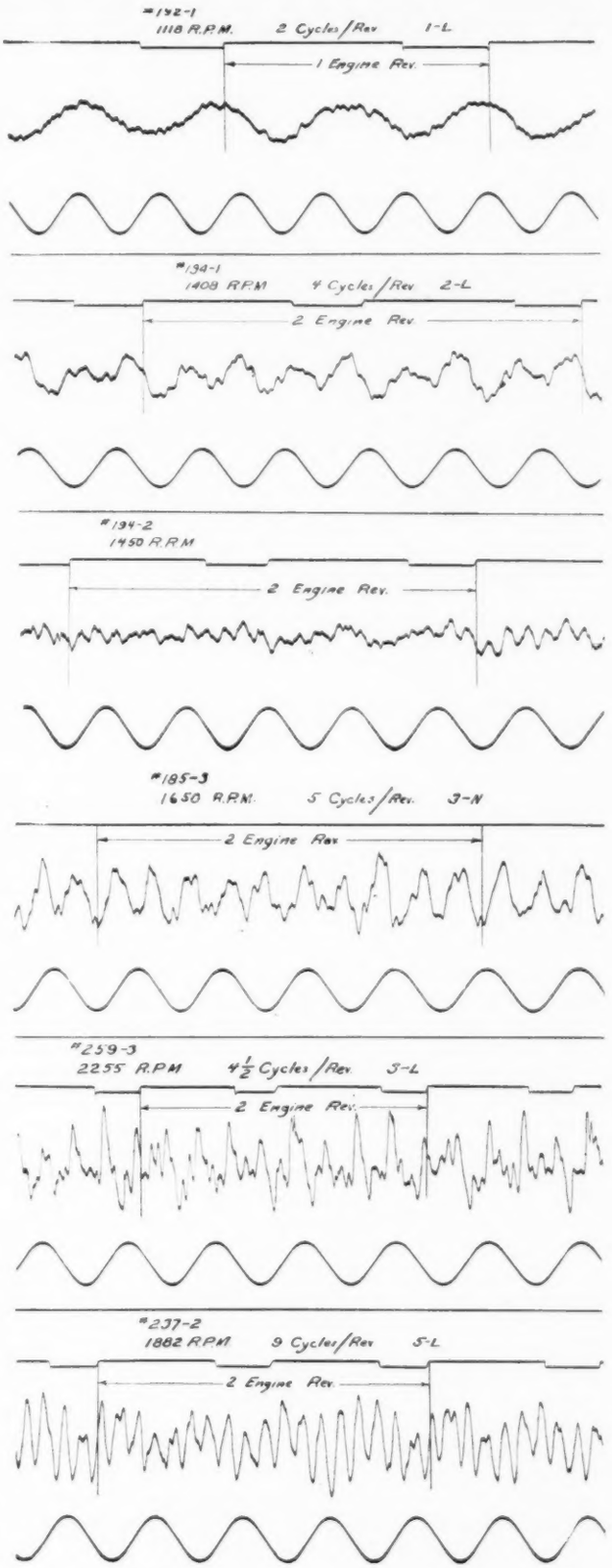

FIG. 8 OSCILLOGRAPH RECORDS OF BLADE VIBRATION

FINISHING INTERNAL SURFACES

Accuracy Depends on Machining Methods Used

By A. W. SCHNEIDER

HEALD MACHINE COMPANY

WHILE there has been constant development in the art of finishing internal surfaces since the advent of the ancient bow drill, the improvement in methods and machines has been extremely rapid during the last decade. Through these improvements it is possible today, in commercial production, to obtain a finish and accuracy in holes which could have been obtained a few years ago only at high cost in the best toolrooms. The methods of obtaining internal finishes are drilling, reaming, broaching, bearizing, honing, precision boring, and grinding.

DRILLING

Drilling is still a prime factor in finishing holes where accuracy is not required. The drill is primarily a means of creating a base hole in blank material, or, in the case of a core drill, of removing the irregularities of a cast hole and preparing it for a finishing operation. For holes requiring size tolerances of less than 0.0005 in., some further operation is required. As a finishing method, therefore, drilling can be used only for clearance holes.

REAMING

The sizing and finishing of holes by means of reaming with a limit of 0.001 in. for size is still economical and popular, since the basic machine equipment is usually low in cost. Reamers to be at all effective should be mounted so as to allow them to "float" when cutting. When the reamer floats in the work it follows the previously prepared hole, and therefore the hole is not much straighter than the rough hole, although the finish is fair. Since the reamer cuts along its length, any tendency of this tool to correct straightness causes the reamer to cut deeper on one side than on the other, with the result that an oval hole is produced. With holes in thin sections there is a decided tendency to force out the metal which has been undercut, and where there are supporting ties there is a noticeable change in the size of the hole opposite the ties.

While these features are not particularly objectionable in soft steels and cast iron where surface finish is not required, they are a source of considerable trouble when reaming softer metals and alloys. It requires considerable skill to sharpen reamers for cutting bronze and brass and also patient stoning of the cutting edge to obtain size and finish. Many of the new aluminum alloys wear the cutting edges of reamers so rapidly that the maintenance cost prohibits their use. The tools must be sharp at all times or a tearing action results in a ruined hole.

Few concerns apparently keep accurate records of reamer maintenance and do not appreciate the fact that with a size tolerance of 0.0006 in. in bronze, the cost of reamer maintenance alone runs from $0.003 to $0.006 for finishing a single hole 0.75 in. in diameter and 0.75 in. long.

Contributed by the Machine Shop Practice Division and presented at a meeting of the Cleveland Section, Cleveland, Ohio, September 11, 1935, of The American Society of Mechanical Engineers.

Reamers are therefore useful only for holes where there is an allowable tolerance of 0.0005 in. for roundness, 0.002 in. in 6 in. for straightness, and 0.001 in. for size. Where there is a required relation of the hole to a flat surface or to another hole, even several of the expensive operations of hand-reaming in line-reaming fixtures will not give required results. On blind holes, excessive relief at the bottom of the hole is required in order to ream to even approximate size and straightness.

BROACHING

Broaches like reamers have a decided tendency to be influenced by the condition of the previously prepared hole. As in reaming, any attempt to straighten the hole tends to produce oval holes. Normally, the cutting speed of broaches is held well under that of a reamer so that the tool life is considerably longer. However, once the broach has been worn below the low limit it has to be replaced. While there has been considerable improvement in broaching equipment in recent years, it is still very difficult, if not impossible, to broach a hole in true relation to another hole or face.

On favorable shapes and sections of work it is possible to produce economically holes with a roundness tolerance of 0.0005 in., a straightness tolerance of 0.002 in. in 6 in., and a size tolerance within 0.00075 in. Naturally, this method cannot be used with blind holes. On parts having thin sections around the hole, however, the broach, when it begins to lose its sharp cutting edge, tends to swell the hole in passage, leaving the hole with tight spots opposite the thin sections. In many stringy materials the dulling broach tends to pick up a chip and tear a groove along the surface of the hole. This groove is extremely objectionable in holes which have to retain pressure, and for this and other reasons any marks are to be avoided in the finished surfaces of articles offered for sale.

BEARIZING

The finishing of internal surfaces by rotating hardened members at comparatively high speed, thereby removing slight irregularities of reamed or bored holes by a process of hammering or rolling, has made considerable progress in fields where a comparatively smooth internal finish is desired. Reamed holes and rough-bored holes have finishes with peaks and valleys, the height of the peaks being dependent to a great extent on the accuracy of the driving spindle. Bearizing knocks off the peaks by forcing the metal into the valleys, and a smooth and comparatively even surface is thereby formed. The operation is not corrective of roundness or straightness of a hole, but is primarily a correction of improper surface finish.

HONING

Surface finishing by honing utilizes a bonded-abrasive bit in a rotating and reciprocating spindle. The process tends to reduce the height of the peaks of previous machining operations by smoothing off the tops of the higher peaks and bringing the irregularities to a comparatively even height. The method is not particularly a sizing operation nor is it a corrective opera-

tion for roundness or straightness of holes. To be effective, the size, roundness, and straightness should be machined in previous operations, leaving for this method only the final smoothing out of surface irregularities.

By selecting the proper feed and tool shape, the surface finish of precision-bored holes can approach that of a medium or satin finish in a honed hole. However, in some cases it is more economical to use higher boring feeds and add a honing operation for high finish.

PRECISION BORING

Precision boring, or diamond boring as it is sometimes called, is a rather recent development. Although several applications of this method were made on production work as early as 1920, it was not until 1928 or 1929 that satisfactory equipment was first introduced. Rapid strides have been made with this method of boring by employing the well-known toolroom practice of using a single-point cutting tool for generating a straight, round hole and using either a diamond or a cemented-carbide tool for high cutting speeds. In developing the precision-boring machine it was necessary to take several important factors into consideration. Vibration in the machine itself or in the spindle is objectionable, not only on account of the chatter which is reproduced in the hole but also on account of the widening use of the cemented-carbide tools which are susceptible to shock. Therefore, it was necessary to eliminate vibration to increase tool life. Boring spindles running up to 5000 rpm require a mounting which cannot have a run-out of more than 0.0001 in. and a drive which does not introduce vibration. The relation of the table travel to the axis of the boring spindle must be accurately maintained and the moving member must have a smooth drive. Such machines are now available.

With tool material which allows cutting speeds of approximately 450 fpm on cast iron and up to 1500 fpm on brass and aluminum alloys, it is possible now, with feeds of from 0.002 in. per revolution up to 0.007 in. per minute, to duplicate, and in most cases improve, the finish obtained by either reaming or broaching with no increased labor cost. In addition, this method will finish holes in relation to other holes or surfaces within limits not obtainable by other methods, regardless of the condition of the previously roughed holes.

It is now the generally accepted practice in automotive manufacturing plants to finish such important holes as piston-pin holes where (1) the size tolerance is usually maintained under 0.0003 in., (2) the hole is held perpendicular to the piston skirt within 0.0004 in., and (3) the opposing holes in the piston must be straight within 0.0001 in. to 0.0002 in. Bronze bushings in gears are bored true to the pitch lines of gears. Connecting rods have their opposite holes bored parallel and to close tolerances. The most recent development has been the boring of the cylinder blocks themselves. Several years ago automobile-engine cylinders were ground to obtain the necessary roundness and straightness. This operation was so slow that reaming was substituted. The development of the precision-boring machine now permits these blocks to be bored with not only a saving over the reaming method, but with the reduction of size tolerance from 0.002 in. to 0.0005 in., of roundness tolerance from 0.001 in. to 0.0002 in., and of parallel tolerance from 0.002 in. to 0.0002 in. in the length of the bore.

In manufacturing household refrigerators where extremely close limits must be maintained, not only on account of the performance of the unit but also because of the safety factor, precision boring was adopted practically from the start as being more accurate and more economical than any other method. The comparative ease and simplicity of maintaining size, straightness, and alignment of holes is resulting in the rapid improvement of this method in all industries where quality of product is an important factor.

In addition to finishing open holes this method is particularly adaptable to the finishing of blind holes. Because of the type of tool used, a blind hole can be finished to within a few thousandths of the bottom without any necessity for an undercut or relief; and frequently at the same time portions of the bottom of the hole or surfaces at the outside of the hole can be finished perpendicular to the hole without changing the tool setting. This is of particular importance in the preparation of antifriction-bearing holes, valve seats, and similar work.

Because of the rigid requirements in the automotive, airplane, electrical refrigeration, quality valve, and similar fields, the development of standard precision-boring equipment is progressing rapidly, since it affords increased accuracy without increased cost. The hydraulic feed of the internal grinder, already developed for a smooth feed with the flexibility of change of table feed, was simplified for adaptation to precision-boring machines. Through hydraulic control it is comparatively simple to work out (1) automatic cycles of rapid traverse from loading to boring position, (2) automatic slow-down to boring feed, (3) still further reduction, if necessary, to facing feed, and (4) complete stop to allow spindles to come to rest before the table automatically returns at rapid traverse to rest or loading position. With hydraulic pressure in the machine proper it is possible to use this power for hydraulic clamping of work, as well as for transverse or rotary hydraulic indexing of fixtures. The base machines are of rugged construction and particular attention has been paid to the elimination of vibration. Any auxiliary units such as hydraulic pumps and electrical motors, which may introduce vibration, usually are insulated carefully from the machine proper. The boring spindles, following closely the design of high-speed grinding spindles, are improved still further for truer running qualities. Force-feed lubrication of all moving surfaces is used normally to increase smoothness of operation. As the result of these improvements, holes bored in the softer materials are equal to or better than the surface finish of a good ground hole.

GRINDING

The finishing of holes by grinding has been a standard for obtaining fine finish of holes and for maintaining the relation of holes to other surfaces. Since the advent of precision boring, many of the softer materials formerly ground are now bored. However, there is not as yet available a cutting tool which will machine satisfactorily materials harder than approximately 30 Rockwell C, and therefore internal grinding is still the only satisfactory method for finishing such materials.

The improvement in grinding technique in the past 15 years has also been quite rapid. This is emphasized by the fact that in 1920 the average production on transmission gears with a hole $1^1/_4$ in. in diameter and $1^1/_2$ in. long was about 20 per hour, while the production today on the same gear is about 120 pieces per hour. The improvement in grinding can be appreciated further from the fact that in 1920 the tolerance for size was 0.001 in. and required a highly skilled operator, while today semiskilled operators work within a size tolerance of 0.0005 in. and in many cases within 0.0003 in.

The sequence of operations in 1920 called for the operator to chuck the piece, indicate it for trueness, advance the wheel head and table by hand to grinding position, engage the automatic table motion, engage the mechanical cross feed, grind, back off the wheel, run out the table by hand, stop the work spindle, and determine the size by means of a hand plug gage.

It was necessary usually to repeat the operation at least twice before the hole was finished to size. Dressing of the wheel was a hand operation performed at the discretion of the operator.

The application of the hydraulic cylinder to reciprocate the table was the next important development. Hydraulic actuation provides not only smoother table operation through elimination of gears and clutches, but it also provides for a more effective table speed for each element of the grinding cycle. By means of a throttle for controlling the flow of oil into the cylinder it is possible to obtain rapid advance of the wheel into the hole, reciprocate the wheel at the proper roughing speed, rapidly withdraw the wheel to truing position, dress it at a proper truing speed, return it to the work at high speed, slow down to a finish grinding speed, and finally withdraw the wheel to rest position at high speed.

Even with these improvements it was still necessary to stop the machine and try a plug gage for size. The next logical developments were those of automatic sizing. One of the first attempts at sizing utilized a diamond-pointed finger connected to a dial indicator. The finger extended into the hole with the diamond point bearing on the surface opposite the grinding wheel. By watching the indicator, the operator would stop the feed when size was reached. This method, however, was not adaptable to splined holes nor to holes of small diameter.

The next development was the substitution of automatic plugging for hand plugging. In this method a plug gage was mounted at the back of the hole, and each reciprocation of the table brought it up against the work. When hole was ground to size the gage entered the hole and the machine was automatically stopped. This method was a decided step forward on open-end work, but was not applicable to blind-hole nor taper work.

Therefore, the dial-indicator method was developed further. First, two electrical contact points were substituted for the dial. As the finger in the hole approaches the limit of roughing size, the first electrical contact is made. The contact is connected to a magnet which, by tripping a latch, allows the table dog to slide and give the table an extended stroke beyond the work. Here, another important feature was added to the machine. The same magnet operates a hydraulic valve which moves the diamond dresser down to truing position so that when the table brings the wheel from the hole, the wheel passes across the dresser and is automatically trued. With the dressing finished, the wheel re-enters the hole and grinds until a second electrical contact indicates that the finished size is reached. The table then moves rapidly to rest position and the work is ready to be removed. The automatic dressing cycle has proved indispensable on many jobs. The wheel is always sharp, clean, and straight for light finish grinding and therefore allows faster cutting, produces smoother finish, and practically eliminates the tendency to grind taper or bell-mouth holes.

This machine is still not suitable for finishing splined or small holes because the finger which is in contact with the inside of the hole takes up some room. However, while it is not practicable to grind to close limits by merely feeding the wheel a definite distance into the work, on account of the many variables encountered, it has been determined that if a hole is rough ground to within 0.002 in. of size and then the wheel trued in definite relation to the hole, it is possible, with a sharp wheel and fine feed, to feed the last two thousandths at a definite rate and to hold the size well within 0.0005 in.

Therefore, it has been possible to remove the indicator finger from the hole and substitute a cam on the cross-feed hand wheel and mount the electrical contacts on the base of the cross slide. By using auxiliary automatic compensation for wheel wear and for wheel-dressing requirements, these contacts on the slide are kept in a constant relative position to the cam on the hand wheel. By this method of sizing it becomes possible to grind all types of open, straight, taper, splined, and blind holes.

With the previously described cycle of automatic roughing and finishing, together with the automatic wheel dressing as an intermediate step, the next step was to add this cycle to the automatic gaging machines. This was accomplished by mounting two gages in tandem. The forward or roughing gage is about 0.002 in. smaller than the finishing gage. When the hole is ground to the roughing limit, the roughing gage enters the hole and starts the automatic dressing cycle. After being dressed, the wheel returns for finishing the surface at finishing speed. When the hole is ground to size, the finish gage enters the hole, and as soon as the electrical contacts are made the wheel backs off and returns the machine to rest position.

Another recent development for internal sizing utilizes air pressure. Air under a pressure of approximately 2 lb per sq in. is led to a finger assembly mounted on the bed of the machine. A diamond-tipped sizing finger extends into the hole in contact with the finished surface. Another stationary finger is in contact with the outside of the chucking device or a bracket mounted on the head. As the grinding proceeds, the sizing finger moves toward the stationary finger, thereby decreasing the air gap and causing air pressure to be built up in the line. The mounting pressure, operating through a mercury switch, closes a first contact which completes the roughing cycle. After dressing the wheel, the operation continues until a second contact at finish size is closed, which causes the table to move out to rest position.

The method, like the other finger indicating methods, uses valuable space in the hole which limits the diameter of the grinding wheel, especially in holes which are under 2 in. in diameter.

While there has been a marked improvement in the accuracy of holding fixtures for internal grinding, the best fixtures manufactured will not chuck and hold work so as to give a concentricity with the outside diameter better than 0.0002 in., and this concentricity naturally cannot be obtained without a hole the outside diameter of which has been prepared carefully for mounting the fixture. This tolerance was not satisfactory to many users, especially the roller-bearing manufacturers. Therefore, the method known as the internal centerless-grinder method was developed to meet closer requirements of concentricity.

In this method of grinding the work is rotated on the outside diameter of the hole between three rolls, one of which is the driving roll for rotating the work, while the other two are the supporting rolls. The grinding wheel grinds in the hole opposite the larger driving roll, thus grinding the wall of the piece to uniform thickness. The size of the hole can be controlled automatically by several of the previously mentioned sizing methods, and practically all types of open, tapered, straight, splined, and blind holes can be ground. The work, of course, must have a continuous and concentric outside finished surface in contact with the rolls. By this method such pieces as bushings and bearing races can be finished externally and the holes then ground to a concentricity tolerance of approximately 0.0001 in.

In addition to holding such tolerances this method adapts

(*Continued on page 232*)

A New GAS CALORIMETER

Based on the Principle of Thermal Balance

By RAFAEL W. KEITH

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THE PRINCIPLE of thermal balance differs radically from that customarily used in calorimeter design. Instead of obtaining the measurement of the heating value of a gaseous fuel by the weight and temperature rise of a fluid of known specific heat, a standard source of heat is used and two temperatures are matched in separate sections of a current of air.

A calorimeter based on the principle of thermal balance has certain highly desirable features. First, there is no need of measuring the temperature rise of the working substance; therefore, calibrated thermometers are not required. Second, the instrument compensates automatically for such disturbing influences as heat losses, changes in barometer, changes in room temperature, and changes in the specific heat of the working substance. Third, the use of the principle leads to an intrinsically "self-checking" calorimeter whose correct calibration can be verified in a few minutes without the use of external standards.

All the foregoing advantages are secured without any special compensatory devices, and the instrument gives a continuous record of the net or lower heating value of the test gas. This record requires no computations or corrections, as the calorimeter measures directly the heating value under standard conditions.

Besides its application as a recorder of gaseous heating values, the new calorimeter may also be used as a means of controlling the heat output of gas flames. This is desirable in automatic machines that use gas burners, such as those used for the automatic manufacture of electric-light bulbs.

The principle of thermal balance is illustrated diagrammatically in Fig. 1. Two thermally insulated chambers are involved, a primary chamber where the fuel to be tested is consumed in a burner, and a secondary chamber where a standard source of heat is placed. The latter may be either an electric heater, or a burner consuming gas of known heating value. The choice between the two depends chiefly on the application of the calorimeter.

The working substance, which consists almost entirely of room air, is drawn through the calorimeter by means of a small suction blower, not shown in Fig. 1. The fluid first enters one leg of the heat exchanger where it is slightly increased in temperature. It then goes through the primary chamber and is warmed further by the combustion of the test gas. About 500 volumes of air flow through the primary chamber for every volume of test gas consumed in the burner.

The fluid leaving the primary chamber is then admitted to another leg of the heat exchanger and is cooled to a temperature close to that prevailing at the inlet of the primary chamber. It then is sent through the secondary chamber and its temperature is again increased by the standard source of heat located in that chamber.

The research reported in this paper was conducted in the laboratories of Cornell University. The author expresses his appreciation to Prof. Hermann Diederichs for the help and encouragement received during the course of the work, and to Prof. Frank O. Ellenwood, who read the original manuscript and offered valuable suggestions.

The heat exchanger, whose actual construction is somewhat different than the simple diagrammatic representation of Fig. 1, has a large heat-transfer surface and is designed to maintain the fluid temperatures at the inlet of both chambers respectively equal to each other within at least 0.01 F.

The respective outlets of the combustion chambers are equipped with the two bulbs of a differential thermometric device that reads zero if the two chamber outlet temperatures are the same; but if this equality is lost, the pointer will move to the right or left, depending on which chamber is warmer.

When the instrument is in operation, the rate of heating in the chambers is automatically varied so as to make the differential thermometric device read zero. Under these conditions, the fluid current undergoes the same temperature increment in both chambers, and therefore, the rate of heating produced by the gas of unknown heating value is the same as the rate of heating produced by the standard source of heat.[1]

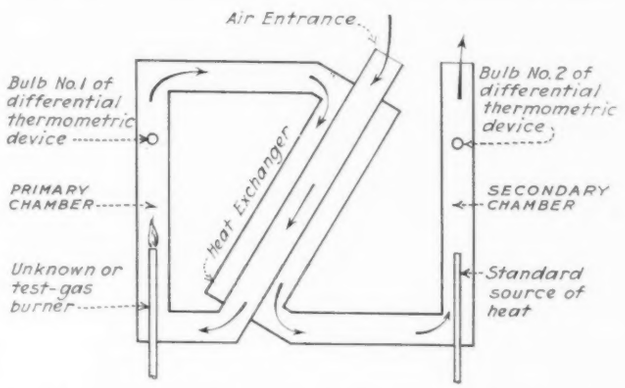


FIG. 1 DIAGRAMMATIC REPRESENTATION OF A THERMAL-BALANCE CALORIMETER

There is no need for corrections for heat loss, inasmuch as both chambers are of identical construction and, therefore, their respective rates of heat transfer to the room are the same. Similarly, it is not necessary to know the specific heat of the working substance because the same fluid circulates through both chambers.

Furthermore, no corrections for condensation of water of combustion are needed because no such condensation ever takes place. Condensation does not occur because of the extremely large volume of air that is supplied in relation to the volume

[1] The fact that the burner in the primary chamber consumes a slight portion of the oxygen in the current of air and that it adds products of combustion to the fluid current does not produce an error because the same fluid current subsequently circulates through the secondary chamber. In other words, the effect produced by the combustion of the test gas appears in both chambers.

When a burner is used as the standard source of heat in the secondary chamber, a slight increase occurs in the heat capacity of the current of fluid going through that chamber. This increase is compensated for by means of an initial adjustment that will be described later.

of gas burned, and also because the products of combustion are not cooled down to room temperature.

APPLICATION TO THE AUTOMATIC RECORDING OF GASEOUS HEATING VALUES

One of the arrangements used in practice is illustrated diagrammatically in Fig. 2, and photographically in Figs. 5, 6, and 7. A gas of known heating value, for example, ordinary acetylene from a cylinder, is used as the standard source of heat. The standard gas is supplied to the burner in the secondary chamber at a constant-volume rate by means of a motor-driven metering pump. The particular rate used in practice is about 4 cu in. of gas per min, and thus one cylinder of acetylene will last for about a year of continuous operation.

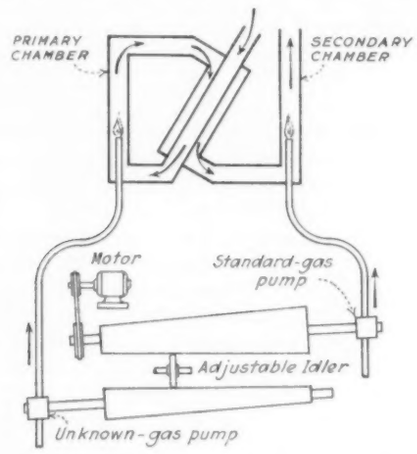


FIG. 2 ARRANGEMENT USED FOR THE MEASUREMENT OF THE HEATING VALUE OF GASES

The gas to be tested for heating value is supplied to the burner in the primary chamber by another metering pump. This second pump is driven from the first through a variable-speed transmission, which consists of two cones with a movable idler interposed between them.

When initially adjusting the instrument, the idler is placed so as to give a one-to-one pump-speed ratio, and the standard gas is sent to both pumps. The constant of discharge of one of the pumps is then varied (by turning an adjusting screw) until thermal balance is secured.[2]

Then the gas to be tested for heating value is sent to the primary-chamber pump and the idler position changed until thermal balance is again secured. The new pump-speed ratio, or idler position, is a direct measure of the heating value of the test gas; for in order to secure thermal balance under the new condition, the test-gas burner must produce exactly the same rate of heating as was produced by the standard gas used in the primary chamber during the initial adjustment of the instrument.

In an actual instrument the idler position is controlled automatically by a system of relays actuated from the differential thermometric device. A recorder pen is carried on the yoke of the idler and this pen draws a record of the heating value of the test gas on a moving paper chart. With the instrument thus automatized, its correct adjustment is simple to check, inasmuch as all the operator has to do is to shift a three-way valve and send standard gas to the primary-chamber pump. The location that the recorder pen assumes when the valve is shifted tells at a glance whether or not the instrument is properly adjusted, and if by any chance adjustment is needed, then all the operator has to do is gradually to turn a screw until the recorder comes to the point corresponding to one-to-one pump-speed ratio.

One interesting quality of the thermal-balance calorimeter is that a high accuracy is secured with a differential thermometric device of relatively low absolute sensitivity. If the increase in temperature of the fluid flowing through the chambers is 100 F, for example, then a thermometric device that will shift when the chamber outlet temperatures becomes unequalized by one-tenth of a degree will give an overall accuracy in the result of one part in 1000, or one-tenth of one per cent. It should also be carefully noted that the accuracy does not depend on the calibration of the thermometric device. All that is required of such a device is that it shall read zero when the temperatures are equalized and that it shall shift to the right or left as the calorimeter tends to lose its condition of thermal balance.

The particular type of thermometric device that may be used depends to some extent on the application of the calorimeter and also on the designer's likes or dislikes. The author has used successfully three different types of thermometric devices. These are: (1) A bank of thermocouples acting on a polarized relay; (2) a specially designed Wheatstone-bridge circuit, also with a polarized relay; (3) a differential mercury-contact U-tube thermostat based on the change in vapor pressure of a fluid.

CONTROL OF THE HEATING VALUE OF MANUFACTURED GAS

The previously described recorder is particularly suitable for applications involving a considerable range of the heating values to be measured, such as would occur when a number of different gases are to be tested. For application to the control of the heating value of manufactured gas all the instrument has to do is to indicate the departure from a predetermined heating value. In this case further simplifications can be effected and additional features secured.

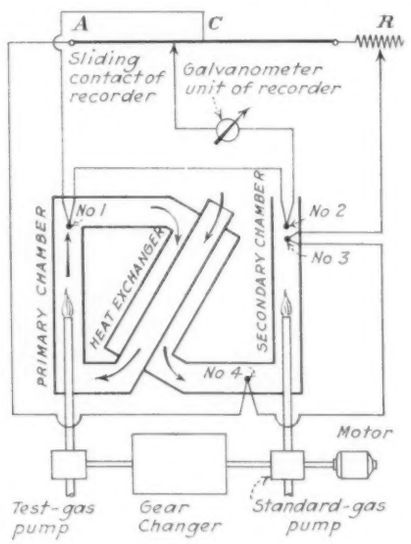


FIG. 3 ARRANGEMENT USED FOR THE CONTROL OF THE HEATING VALUE OF MANUFACTURED OR OF NATURAL GAS

[2] It should be noted that this adjustment automatically compensates for the slight increase in the heat capacity of the working substance that is produced by the combustion of the standard gas in the secondary chamber, for, in order to secure thermal balance with the standard gas in both pumps and the pumps running at one-to-one speed ratio, the standard gas pump must discharge slightly more gas than the primary-chamber pump.

The general arrangement of the instrument for this last application is illustrated diagrammatically by Fig. 3. Instead of an infinitely variable speed transmission linking both pumps, a simple and rugged gear-change box is used. This gear box has a one-to-one ratio for use in initially adjusting the instrument and also for checking correct adjustment. Then it also has an operating ratio that is numerically equal to the ratio of the heating value of the standard gas and the figure to which it is desired to maintain the heating value of the gas that is to be tested.

A standard potentiometer type of recorder equipped with a center-tapped slidewire is connected with thermocouple pairs in the chambers in the manner shown in Fig. 3. Only single pairs of couples are shown in this figure, but it should be understood that in an actual instrument a series of ten or more pairs is used in order to secure greater sensitivity.

From inspection of Fig. 3 it can be seen that when the calorimeter is under conditions of thermal balance, the sliding contact, or recorder pen, of the potentiometer is directly under the center tap. This means that when the test gas has the desired heating value, the pen will place itself at the middle of the chart, and also that it will shift to the right or left depending on whether the test gas increases or decreases in heating value.

The main advantage of this design of calorimeter is that the scale can be made broad and easy to read, as no zero is required. Furthermore, the instrument will indicate when the gas has the desired heating value regardless of the calibration of the thermocouples or of the adjustment of the current in the slidewire of the potentiometer. Last, but not least, the correct adjustment of the metering pumps can be verified in a few minutes by simply placing the gears at one-to-one pump-

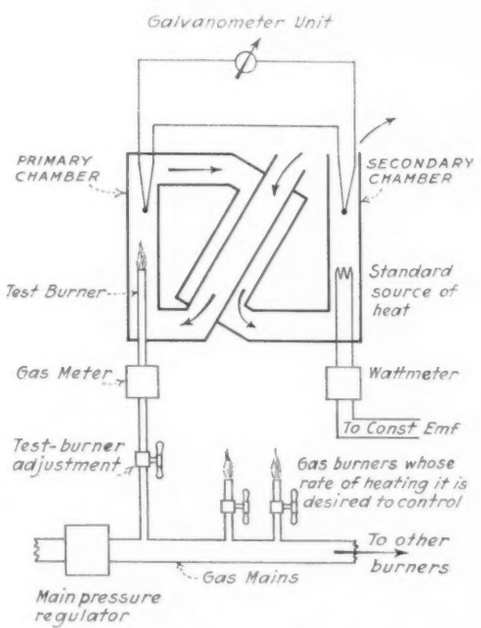


FIG. 4 ARRANGEMENT USED FOR THE CONTROL OF THE RATE OF HEATING OF GAS FLAMES

speed ratio, sending standard gas to both chambers, and then observing whether the recorder pen assumes a position at the middle of the chart. If adjustment is needed, then this can be made as in the previous design; namely, by turning an adjusting screw that is provided for the purpose in one of the metering pumps.

APPLICATION TO THE CONTROL OF RATE OF HEATING FROM GAS BURNERS

Many automatic machines that use gas burners require that the rate of heating from these burners be maintained constant. This condition cannot be secured with a pressure regulator alone, inasmuch as the regulator only keeps the pressure at a

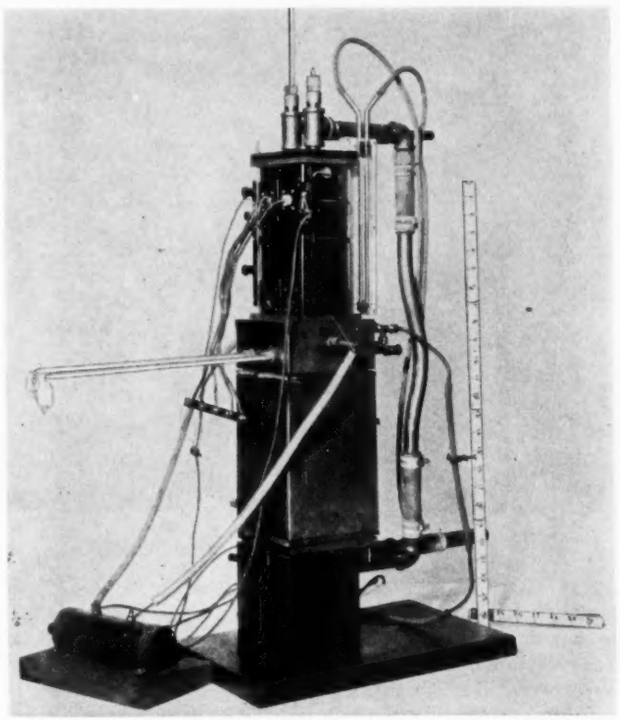


FIG. 5 EXTERNAL VIEW OF EXPERIMENTAL CALORIMETER

fixed amount above the atmosphere and has no control on the density or on the heating value of the gas.

The thermal-balance calorimeter may be arranged to respond to all factors that tend to vary the rate of heating of gas burners connected to a given gas main. Furthermore, the instrument may also be made to change the adjustment of the pressure regulators in the main, and in this way keep a constant rate of heating from each of the burners connected to the main.

The general arrangement used is diagrammatically illustrated by Fig. 4. An electric heating element is used as the standard source of heat. This heater is supplied with a constant voltage, and a wattmeter is used in order to have a visual check on the constancy of the power input to the heater.

When the calorimeter is to be put in operation, the valves of the burners to be controlled are first adjusted. Then the valve of the burner of the calorimeter is adjusted until conditions of thermal balance are secured. Any effect tending to change the rate of heating of the burners connected to the main will also affect the calorimeter burner, thereby causing the galvanometer unit to move from its neutral position. If the galvanometer is connected with the main pressure regulator by means of a relay control, then the gas pressure in the mains can be made to vary to compensate for any effect that may tend to change the rate of heating from the burners.

CONSTRUCTIONAL DETAILS OF APPARATUS AND EXPERIMENTAL RESULTS

The external appearance of an experimental thermal-balance calorimeter is shown in Fig. 5. The flow of air is produced by

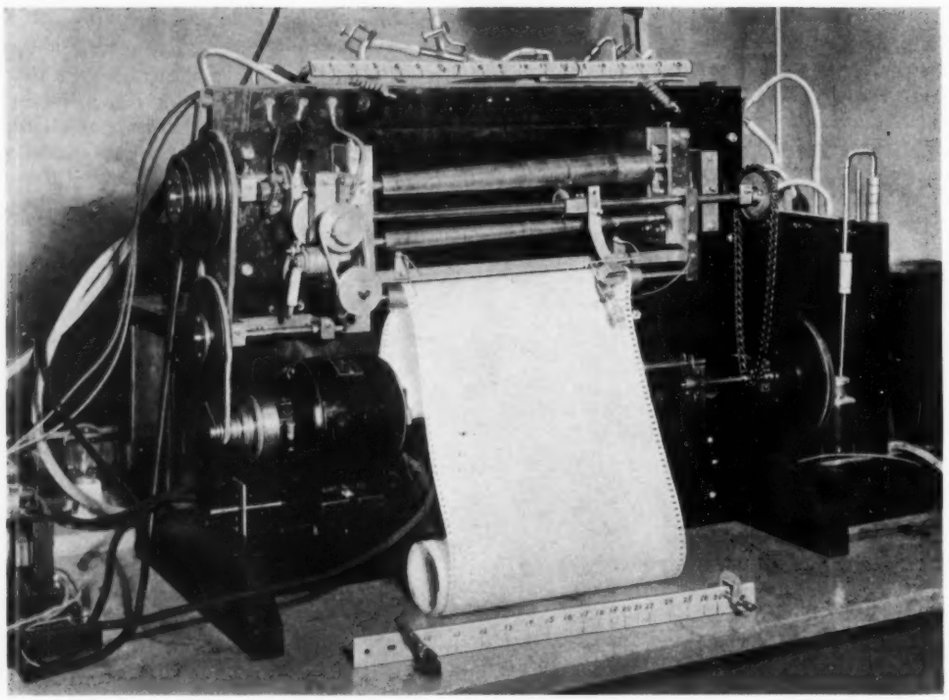


FIG. 6 RECORDER MECHANISM

a suction blower, not shown in the picture. Suction is used so that the burners will go out if the power fails. The induction coil shown in the picture is used to light the burners when first starting the instrument.

The lower part of the calorimeter is the heat exchanger. This is of the flat-plate type, and has a heat-transfer surface of 13 sq ft in a volume of about $\frac{1}{4}$ cu ft. The rate of heat transfer for this entire surface is between 1 and 2 Btu per min.

The combustion chambers are located side by side on top of the heat exchanger and have glass windows through which the combustion can be observed. These chambers are equipped with a permanent thermometric device that consists of ten thermocouple pairs connected in series. In addition, two holes are left for the insertion of other types of thermometric devices and for the comparison of their relative merits. The illustration shows the leads of a special differential thermometer based on the Wheatstone bridge, coming out of the holes. The mercurial thermometers shown were used for running heat balances and determining the various chamber characteristics, but these thermometers are not used in the actual operation of the instrument.

The experimental recorder mechanism is shown in Fig. 6, which also shows the main motor drive, the variable-speed transmission, and the idler wheel and recording pen. The idler position is controlled by a reversing motor located on the rear of the recorder. This motor is linked with the thermometric device by means of relays.

The metering pumps are located on the rear of the recorder and are driven from the cones by means of the worm gears shown in Fig. 6. These metering pumps are a new development; therefore they will be described briefly. Fig. 7 shows the various parts of one of the pumps. The little buckets on the rotor are connected to the hub by means of hollow spokes. When in operation, the rotor runs partly submerged in water, and as it rotates, each bucket entrains a small but definite volume of gas. This gas is then discharged through the holes in the hub from which it is collected by an inverted funnel as shown in the left view of Fig. 7.

A process of electrodeposition was used for the manufacture of the buckets in order to assure equality of their respective internal volumes. A number of white-metal die castings were made, placed in a bath, and heavily electroplated. When the plate became thick enough, the white metal was melted out, leaving solid copper shells, each of the same internal volume.

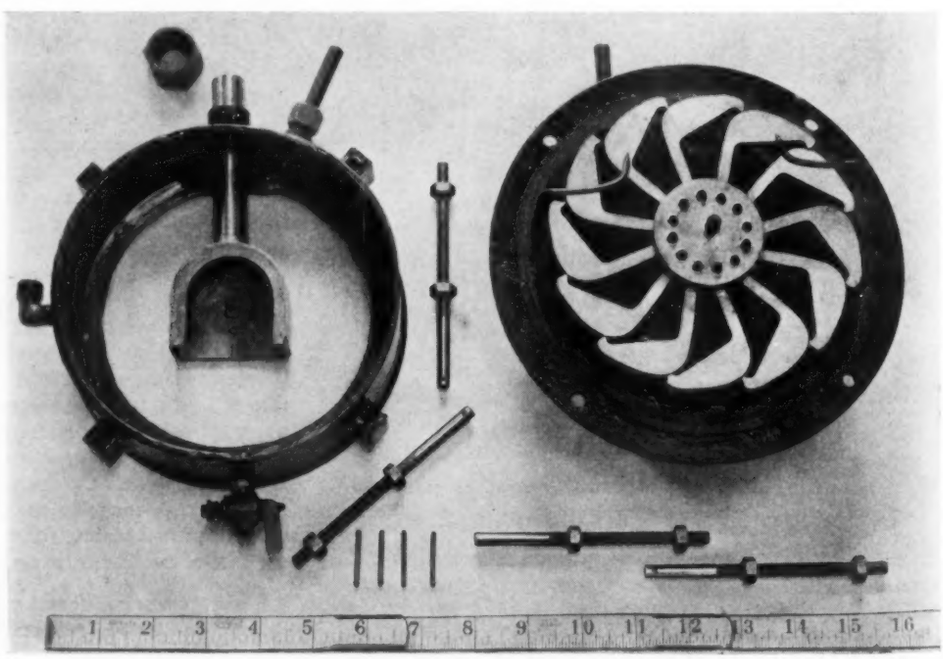


FIG. 7 CONSTRUCTIONAL DETAILS OF METERING PUMPS

The metering pumps are equipped with an overflow device, not shown in the illustration, and when in operation, a small amount of water is continually added in order to maintain a constant level. The discharge characteristics of the pump may be varied by changing the location of the overflow. This adjustment is easily accomplished by turning a screw. Hook gages are also incorporated in the pump in order to provide a visual check on the correctness of the water level. The operating range of the pump speed is between 0 and 12 rpm. The discharge is about 2 cu in. of gas per revolution of the metering pump.

EXPERIMENTAL RESULTS

Some of the more interesting experimental charts obtained with the calorimeter are shown in Fig. 8. Record No. 1 was obtained while still experimenting with the constructional details of the chambers. In this particular record, "Pyrofax" bottle gas, chiefly propane, was used as the standard gas. For the test gas, acetylene from an ordinary cylinder was provided.

The recorder was left during the week end with a gas of constant heating value in order to determine whether anything disturbed the reading. Much to the surprise of every one it was discovered that the calorimeter read correctly during the day but showed an error during the night. The difference was only about 1.5 per cent, but this was considered serious, inasmuch as the instrument had been designed to record heating values within an accuracy of 0.2 per cent. Investigation disclosed that the error occurred when the steam went off from the heating mains in the building. A test was then run in which the calorimeter was adjusted to read the correct heating value of acetylene with the steam off. When the steam came on another 1.5 per cent difference occurred but in the opposite direction. These tests indicated that the chambers were being unequally affected by radiation from the steam heater in the room, a conclusion that was further corroborated by placing a shield between the radiator and the calorimeter. The combustion chambers were then redesigned and the radiation effect eliminated by proper shielding. This made the irregularity disappear, and the instrument then gave the same reading, whether the steam was on or off.

It should be noted that the thermal-balance calorimeter is unaffected by either heat losses or additions so long as these are distributed equally to both combustion chambers. This condition has been secured in the new design by placing both chambers inside a metal box.

Record No. 2 is interesting because it helped to settle a slight argument between the staff members of the Engineering College and the Chemistry Department of Cornell University. At the time this record was made, the local gas company had just changed from manufactured to natural gas. Both the chemists and the engineers had run tests on the new gas by means of Junkers calorimeters, but their figures did not check as accurately as was expected. The thermal-balance calorimeter was then started and the record occasionally checked with a Junkers calorimeter. The record started on Feb. 6 with the figure the engineers had been getting, and a Junkers test on the evening of Feb. 6 substantiated the value; but late on the afternoon of the next day, and all through the night, the thermal-balance record indicated the chemist's value. A check with the same Junkers calorimeter substantiated the latter figure, thereby showing that the chemists were also right. In other words, the heating value of the gas was fluctuating about 20 Btu from day to day.

This little experience illustrates the advantage of an automatic recording instrument over a manually operated instrument. An automatic recorder gives a continuous record over a long time interval and is therefore preferable to that obtained from apparatus that give results only for the time that the test is run.

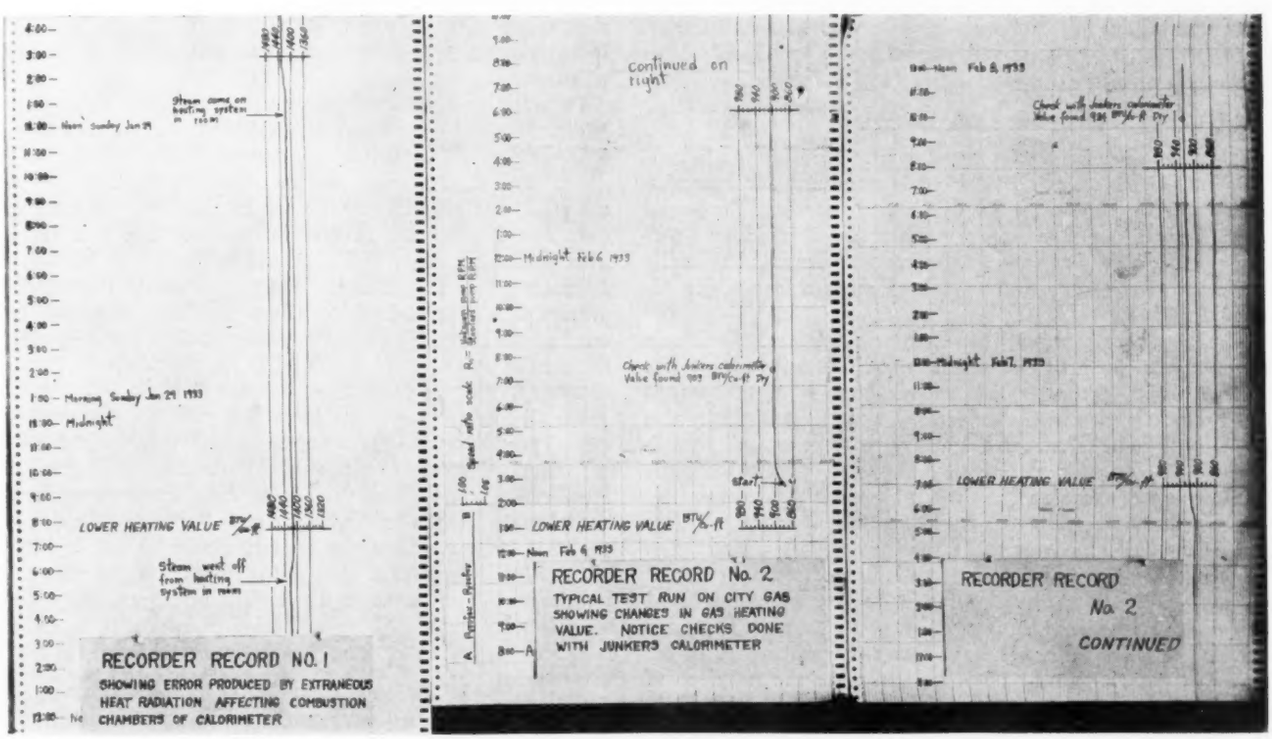

Steam went on heating system in room
Midnight
LOWER HEATING VALUE
Steam went off from heating system in room
RECORDER RECORD NO. 1
SHOWING ERROR PRODUCED BY EXTRANEOUS HEAT RADIATION AFFECTING COMBUSTION CHAMBERS OF CALORIMETER
Continued on right
Midnight Feb 6 1933
Check with Junkers calorimeter
LOWER HEATING VALUE
Start
RECORDER RECORD No. 2
TYPICAL TEST RUN ON CITY GAS SHOWING CHANGES IN GAS HEATING VALUE. NOTICE CHECKS DONE WITH JUNKERS CALORIMETER
Check with Junkers calorimeter
LOWER HEATING VALUE
RECORDER RECORD
No. 2
CONTINUED

FIG. 8 SAMPLES OF RECORDER RECORDS OBTAINED WITH CALORIMETER

LEADERSHIP—*or* SCIENTIFIC SCHOLARSHIP?

By CLEMENT J. FREUND

DEAN, COLLEGE OF ENGINEERING, UNIVERSITY OF DETROIT

MANY, although not all, of the important engineering discoveries of the past have been the result of the tinkering and pottering of persistent men. But scientific study is replacing harebrained invention. In the last 20 or 30 years engineers and industrialists have gradually learned to appreciate that engineering progress is something more fundamental than the superficial improvement of devices, and they have accordingly encouraged engineering research. The colleges have taken up the research idea with such enthusiasm that the research professor is today the smartest figure on the campus, while the mere teacher or counselor of undergraduates, no matter how well he does his work, has become a sorry and neglected drudge. Some even insist that every engineering student be trained in research. "Research is . . . the most important function in the education of a young man who hopes to become worthy of the name 'engineer,' " wrote Prof. Theodore H. Morgan in the *Journal of Engineering Education* for December, 1934.

Researchers from the graduate schools are hailed as the future leaders of the engineering profession. Much depends upon what is meant by leadership. It seems quite obvious that scholars and investigators will become the leaders in the highly intellectual and scientific divisions of engineering. It is not so immediately evident that research is the best training for those leaders in a larger and broader way who control vast enterprises and projects, and inspire and direct hundreds or thousands of men—the administrators of industry.

THE RESEARCH TYPE

The researcher is familiar to all of us. He is an intellectual colossus. He is a specialist, in ferrous metallurgy, or dynamics, or electronics. He is not broad in interest or effort; he cannot be. His studies are so deep and exhaustive that he must confine them to a very narrow area. Famous scientists habitually amaze people by their naive opinions about things which are not scientific.

The researcher is ordinarily a lone wolf. Johnson O'Connor tested several hundred research men and found that subjective characteristics predominated. "The man who chooses to work alone rather than to fit his activities into those of a group will find that research offers opportunities. . ." according to "Engineering—A Career, A Culture," published by the Engineering Foundation.

The scientific investigator is so absorbed in concrete values and quantitative measurements that people often upset him by what they say and do, if, indeed, he notices their speech and actions at all. "His capacity for judicial thinking, based on conflicting evidence, is usually less well developed; and his intuitive faculties, as a rule, have been so overshadowed by his analytical habits that he often fails to sense the reactions of ordinary people."[1]

It need hardly be added that he has but little skill, as a rule, in the handling of men.

THE INDUSTRIAL LEADER

So much for the research scholars with advanced degrees. Now let us take a look at the engineers of the United States, where they are and what they are doing. On the whole, engineers get out of, or stay out of, highly technical or scientific jobs. In 1930 management engaged 40 per cent of all mechanical engineers, and 55 per cent of those over 45 years of age.[2] Seventy per cent of all engineers apparently gain executive responsibility sooner or later, or have it thrust upon them.[3] As long ago as 1919, Dean Dexter S. Kimball wrote: "Today the terms 'engineer' and 'engineering' have almost lost their original meaning and have become synonomous with *systematic accomplishment* and with 'getting things done.' " Engineers have largely become leaders in industry.

Now, what qualifications are required of leaders in industry? Almost everybody thinks he knows but few can write the specification. Prof. Ernest Burton tried it and wrote, "physical energy." Prof. Edwin A. Schell tried it too and wrote, "Among the traits of which the executive requires an unusual allotment, we may mention an innate interest in and affection for people," and "a second characteristic which executives require is a certain strength or power of personality," and "the third quality which appears strongly essential is a scientific trend of mind."

Outstanding leaders are likely not much given to introspection. Possibly they never think about the requirements of leadership at all until they are pressed by the reporter or the ghost writer. It seems Andrew Carnegie thought he was successful because he knew how to laugh. Eugene Grace feels that sound judgment makes the leader. The late Charles Piez, former president of The American Society of Mechanical Engineers, called application and responsibility the most important factors in leadership. Owen D. Young stresses, "conscience and judgment plus the courage to act and willingness to take the penalties of responsibility . . . the scourging honesty of never fooling yourself about yourself."

We all like to think that leadership calls for extraordinary mental power but there seems to be no good reason for thinking so. In their recently published "Executive Ability," Glen W. Cleeton and Charles W. Mason omit intelligence from a list of twenty traits of the executive. Professor Schell points out that "the work of the executive may require a higher level of intelligence than that of his employees, but this characteristic will not serve to distinguish him from many other officials who are not filling executive positions." In fact, it is difficult to find exceptional intelligence mentioned anywhere as a requisite for leadership.

[1] "Report of Investigation of Engineering Education, 1923–1929," vol. 2, 1934, p. 1061, Society for Promotion of Engineering Education.

[2] "1930 Earnings of Mechanical Engineers," MECHANICAL ENGINEERING, vol. 53, 1931, pp. 651–656, 817–823, and 876–882.

[3] "Report of Investigation of Engineering Education," vol. 1, 1930, p. 232, Society for Promotion of Engineering Education.

Of course, the leader must be intelligent but his intelligence is not of the scholarly kind. He is not an intellectual. He has none of the mental superpower which comes of research training. He is not accustomed to contemplation, he is a man of action. He thinks, but to immediate purpose. Frequently he bungles his thinking woefully, but he continues as a leader; nor does the bungling seem to weaken in the slightest degree the security of his position as leader. When he finds himself unable to think out a problem to his satisfaction, or when he has something more important than thinking to do, he hires a doctor of philosophy to do his thinking for him, as he might hire an auditor to check his accounts or a tutor to instruct his son.

Precise, quantitative measurement of ability to manage is impossible. However, Cleeton and Mason have bravely attempted an approximation and conclude that aptitude for leadership is more than anything else "above average ability in a large number of qualities which can be rated or measured." Is this not the answer? Does this not conform to common experience? Is not the leader versatile and broad rather than adept in any line? Is he not a man of great all-around capacity and strength rather than a highly skilled specialist? Does he not direct, coordinate, and inspire the work of experts whose tasks he understands well enough but could not conceivably perform? "It is not necessary that the executive should personally work out the engineering problems of his organization, for he can have a corps of trained experts to do that, but he must be able to analyze their efforts and to know exactly what information he wants and which are the vital points on which to base his decisions." So wrote Alfred Sloan, president of The General Motors Corporation in *Forbes Magazine* for June, 1926.

And the leader is greater than the expert. The architect may be spellbound by the exquisite skill of the stone carver who is executing a bas-relief above the entrance to a public building, but he is greater than the carver because he conceived, planned, and superintended the construction of the entire building, of which the carving is a trifling detail.

RESEARCHER STAYS OUT OF ADMINISTRATION

Since the qualifications for research and for leadership differ so much, it is not surprising that the men who come out of our graduate schools do not become industrial administrators. In 1931 The American Society of Mechanical Engineers published the report of its Committee on the Economic Status of the Engineer.[3] According to this report, engineers with graduate training "tend to stay in strictly research positions and do not become general executives." Prof. M. E. Haggerty ascertained in 1928 that not more than three per cent of the doctors of American universities could be found in business or industry in any capacity, either technical or administrative. Correspondence during the past year with the deans of the graduate schools in a dozen of the more important universities discloses no evidence whatever that any appreciable number of men with advanced degrees either become industrial leaders or care at all for that sort of thing. Most of them go into educational work.

THE FUNCTION OF THE COLLEGES

It is clearly the responsibility of the colleges of engineering to prepare both the scientific or research engineers and the industrial leaders. And in this meaning, chiefs of departments farther down the line are industrial leaders as well as the chairmen and presidents of corporations. After taking the bachelor's degree the research engineer completes his training in the graduate school while the leader proves himself in a strenuous period of practical apprenticeship or experience.

The researcher is so exceedingly important and his importance is so rapidly increasing that the colleges may forget that the researcher must always be very much in the minority. In the nature of things, one or two research engineers must be associated with a large group of development engineers, designing engineers, estimating engineers, plant engineers, production engineers, sales engineers, service engineers, and many others.

PROCEDURE IN THE COLLEGES

Just how shall the colleges carry out their dual responsibility of training for research and training for leadership?

The research phase of the problem should not be difficult. Engineering teachers have grown so enthusiastic about research in recent years that they will readily devise ways and means for properly instructing the undergraduate who looks like good material for the graduate school. There should be comparatively few research candidates in any case and the faculty can adjust courses and activities to the requirements of the individual, who should very soon become definitely the disciple of an inspiring professor.

The management or leadership phase of the problem is not so easy. Conventional engineering subjects largely involve quantitative measurements of material and physical values, while leadership is much more a matter of intangible human values, thoughts, emotions, and viewpoints. Students find it difficult to change from one to the other and to succeed in both. Dean R. E. Doherty, of Yale, feels the need of training for management but admits that he does not know how to go about it.

The faculties of a number of prominent colleges hold that quantitative methods can be applied much further in management technique than they have in the past, and about this doctrine they have built courses in industrial engineering. But these faculties would themselves probably be the last to maintain that such industrial-engineering courses are perfect, or even adequate, leadership training.

On the whole, the familiar engineering curriculum seems to be a reasonably good foundation for leadership experience. In the "Report of the Investigation of Engineering Education" of the S.P.E.E. we read: "Engineering courses fit graduates to a satisfactory degree for the responsibilities of the direction of American industry"[4] and that, in the opinion of most engineering-society members, "the engineer is best prepared for his administrative and managerial duties by a thorough grounding in the technical aspects of his profession."[5] It appears that no upsetting of the curriculum is necessary.

Probably the colleges can best accomplish their objective if they will adopt a procedure in which the following items shall predominate:

1 Variety of courses and activity. Leadership calls for well-rounded character and personality. Hence, the college faculties need to seek breadth rather than specialization in such curriculum revisions as they will make from time to time. Moreover, the student should learn to work and play with his fellows, he should learn cooperation, and give-and-take. Perhaps the student activities, recently somewhat discredited, need to be restored to their former standing.

2 Maintenance of an atmosphere in the college much more favorable to management than obtains at present. This will be heresy to some. After long association with faculty members in the graduate school, the engineering professor has consciously or unconsciously begun to feel that too much

[4] Op. cit., p. 232.
[5] Ibid., p. 404.

practical energy and effort are the mark of the philistine, that the university exists only for intellectual accomplishment, and that the instruction of undergraduates is merely a necessary but wholly annoying by-product.

Nevertheless, the engineering colleges should create an atmosphere and a viewpoint in which leadership fares as well as scholarship. In the illustrations used in the lectures and classes, in the inspection trips, in the counseling of students, both formal and informal, in the casual conversation of the faculty members, in the personalities of lecturers invited to the college, in the granting of distinctions and honorary degrees, in the character of the very pictures hung upon the walls, the ideal of industrial leadership should be honored equally with scholarship.

3 Emphasis on the superiority of the leadership function. The college must not merely elevate leadership to the same level as scholarship but should teach, in addition, that a career of leadership in industry is superior to a career of technical or research engineering. Of course, this holds only within comparable ranks. The chief research engineer is obviously superior to some insignificant foreman, but he is not superior in function to the president of the corporation which employs him. The expert may be the intellectual superior of the administrator but the administrator, if he is a real leader, is greater by virtue of many important qualifications other than intellect.

The research professor will not like this. It will be hard for him to extol virtues which he probably does not himself possess. But he cannot brush aside the judgment of all men through the ages. Kings have always been greater than their counselors, diplomats greater than their secretaries, generals greater than their staffs. The intellectual will always be subordinate to the man of courage, energy, and power, who accepts with enthusiasm large and complex responsibilities.

4 Recognition of leadership in the placement of graduates. The placement officer must give to scientific work and to leadership the same relative emphasis as the teacher does, or should. He must remind his young aspirants to leadership that any kind of work which makes them exercise as many faculties as possible is much better preparation for an administrative job than the intense application of some specific skill, in drafting or calculating, for instance, whereby they may earn a greater immediate income.

THE ENGLISH UNIVERSITY

A superficial reading of this paper may lead to the conclusion that it discredits research. This would be serious indeed in view of the increasing significance of research, and of its fashion at the moment. Nothing has been attempted except a comparison of the career possibilities of scientific engineering work and of industrial leadership, and to point out that men are not judged exclusively by intellectual capacity in the great world of affairs; and it is the great world of affairs in which most of our engineering graduates will go to work.

It may be well to acknowledge, too, that one man may, and often does, combine the highest qualifications for both research and leadership.

Have we not, perhaps, copied somewhat too closely the German ideal of the university, with its intense cultivation of scientific scholarship? Should we not study more carefully the great English universities? At Oxford and at Cambridge young men for centuries have specialized but little; they have studied their history, their traditions and their environment; and they have learned how to live. And out of those ancient centers of broad education have come giants in statesmanship, giants in law, giants in government, giants in colonial administration, giants in industry and in commerce. It may well be that if we introduce into our undergraduate colleges of engineering more of the methods of those great schools, we may train more giants in engineering administration.

Finishing Internal Surfaces

(*Continued from page 224*)

itself to automatic loading. With the driving roll stationary, one of the two supporting rolls is moved outward slightly on a fixed center, which allows an automatic loading arm to lift the pieces between the stationary driving roll and the supporting roll that moved out. With a new piece in place the supporting roll moves back into place and the new piece is automatically located and ready for grinding. With the operator's attention required only for changing the grinding wheel and for loading the work in loading chutes, it is readily possible for one operator to take care of from four to six machines, the machine itself automatically controlling size and concentricity.

TOLERANCES LESS THAN 0.0001-IN.

The question of surface accuracies of less than 0.0001 in. is at present too involved for discussion. Measuring instruments which are accurate enough to determine size, roundness, and straightness of holes to tolerances under 0.00005 in. have just been developed. Investigation of the measurement of surface finishes in an effort to measure and grade finishes is now under way. However, the grading of finish has not yet reached the production stage, and therefore surface finishes for most parts are largely determined by visual inspection. Eventually, a scale will be developed for measuring a finish similar to one of the scales for measuring hardness. Such a scale is certainly needed today in industries where one engineer's conception of a mirror finish corresponds to another engineer's idea of a rough finish. When some suitable scale is finally devised, further progress will be made in consolidating information as to the requirements of finish for a particular service.

Table 1 is submitted as a guide in the selection of the proper method and equipment to suit a particular need of accuracy.

TABLE 1 COMPARATIVE LIMITS OF FINISHED HOLES OBTAINED BY VARIOUS FINISHING METHODS

Method	Roundness	Straightness	Size
Drilling	0.005	0.004	0.005
Reaming	0.0005	0.002	0.001
Broaching	0.0005	0.002	0.00075
Boring	0.0002	0.0002	0.0003
Honing	Note *A*	Note *A*	0.0003
Bearizing	0.0005	Note *A*	Note *A*
Grinding	0.0002	0.0002	0.0003

NOTE *A*: These limits are dependent on the condition of the hole from the previous operation. Holes honed show approximately the same accuracy as the previously machined holes with a possibility of a better surface finish.

AIR-LINE ENGINEERING *and* MAINTENANCE

By L. G. FRITZ and W. A. HAMILTON

TRANSCONTINENTAL AND WESTERN AIR, INC., KANSAS CITY, MO.

DURING the last three years, transport aviation in the United States has undergone a remarkable change. The slow, obsolete equipment has been replaced with fast, modern, all-metal transports, which have made a distinct contribution to the comfort, safety, and speed of air travel.

Equally as important as the changes in the plane itself are the changed methods put into effect coincident with the introduction of the newer transports. The experience gained on the older equipment had driven home to the operators a few fundamental requirements of air-transport operation, which may be briefly summed up as follows:

First, all equipment—aircraft, engine, and associated units—must be standardized as much as possible to permit uniform servicing methods over the entire system and a reduction in inventory, overhaul, and maintenance costs.

Second, sufficient information must be available to the pilot on the ground so that he may construct an accurate plan of flight before take-off. Once in the air, navigational and instrument facilities must be such that the pilot may at any time readily check the flight plan constructed prior to departure. Most major air lines have now in effect, or in progress, programs designed to bring about these desired flight and ground conditions. However, to carry them out effectively, the combined efforts of skilled navigational, radio, airway, meteorological, and maintenance engineering personnel are required.

MAINTENANCE

Jigs and Equipment. In the conduct of aircraft maintenance, a large factor in the efficiency of any shop depends upon the skill and ingenuity displayed in the construction of jigs and equipment. The importance of this factor was greatly emphasized by the introduction of the new transports where provision had been made in the contract specifications for interchangeability of component parts, such as engine nacelles, instrument panels, and control surfaces.

To avoid lengthy tie-up of planes at engine change, a production line on the build-up of engine nacelles has been organized, which will permit an engine change on a Douglas plane to be completed in one hour. The time required to build up an engine preparatory to installation in a plane has been further reduced by designing special tools and equipment and having certain men specialize on the various operations, such as cowling repair, oil-tank overhaul, and exhaust-collector repair. This system has proved successful and is being extended to other parts of the aircraft wherever possible.

One of the worst "headaches" encountered in maintenance is in the design of adequate inspection stands, cleaning stands, supply carts, propeller carts, and similar hangar equipment. These units should be light, easily movable, rigid, and standardized throughout the system. This type of work is often underestimated in view of the more pressing problems of plane and engine maintenance. However, it calls for careful thought on the part of the personnel responsible for the design, and if well done it will pay ample dividends in speedier and more efficient maintenance.

Much attention is also paid to the design of test equipment which will closely parallel operating conditions. For example, a machine for testing overhauled spark plugs has been constructed, which, when a foot lever is pressed, subjects the plug to the current from a standard aircraft magneto and at the same time to a compressed-air pressure of 125 lb per sq in. The operator may then look through a small window in the top of the machine and note whether or not the plug is firing under pressures similar to those existing in the cylinder at the moment of sparking. Many plugs which fire perfectly at atmospheric pressure are rejected after this test.

ENGINE OVERHAUL SHOP

Weight Control. It has been generally observed that airplane weight, apparently like Topsy, "just grows." In the past an airplane's weight seemed to be a function of time—the longer it was in service, the heavier it got—and no one ever was able to account for more than a small portion of the increase.

In an effort to prevent this uncurbed growth, a card index has not been set up on all changes which in any way affect the weight of the airplane. It is also necessary to show the weight involved in a contemplated change, however slight, and secure an approval of this before work is started. Periodically, these cards are totaled and the net increase at that time is called to the attention of all interested persons. To date this has been quite effective in eliminating

Contributed by the St. Louis Section and the Aeronautic Division and presented at the National Aeronautic Meeting, St. Louis, Mo., October 10–12, 1935, of The American Society of Mechanical Engineers.

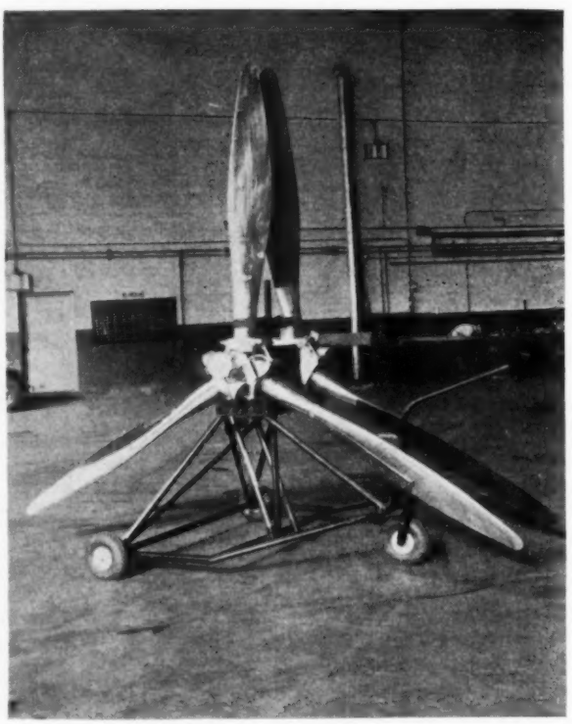
a number of minor changes which would not materially add to the airplane in any way save weight, yet which would have probably been approved under the old order.

Deicers. Deicers have now become generally enough adopted to have definitely passed the experimental stage. The development of the rubber "overshoe" deicer is an excellent example of the results of cooperation between the manufacturer and the operator. In the original test units, little was known of the proper air pressure to be employed, or the speed of inflation cycles. However, both Goodrich and Eclipse, who manufacture the mechanical units of the system, cooperated to the fullest extent in the preliminary flight tests and subsequent service testing, which materially speeded the progress of this development.

One of the more difficult problems in connection with deicing was the design of a suitable spinner to deice the propeller hubs. After considerable effort, and various unsuccessful attempts, a spinner was designed that uses a special type of attaching bolt and snap-in rubber nose cap. This gave a spinner which could be readily removed and easily balanced with the propeller, as an assembly.

Fuel Tests. In order to determine as nearly as possible the most desirable fuel characteristics for our service, extensive fuel tests were run on the motor test stand, the main object being to eliminate as much as possible the tendency toward carburetor icing. These tests produced some interesting results and enabled us to draw up fuel specifications with narrow limitations on the 90 per cent point of the distillation curve, which materially improved our experience in respect to icing. Since that time, the Bureau of Standards has carried on some work on this subject, which seems to point to the 50 per cent point as being a better guide to the icing characteristics of a given fuel. This subject is of great importance, and it is hoped that more study will be made of the carburetor icing problems. Foreign tests of a sylphon-valve arrangement, which automatically clears the carburetor with a spray of alcohol into the venturi under incipient icing conditions, have been closely followed. The alcohol reduces the adhesion of the ice to the metal and is said to be very fast in its action. This interesting development is still in an experimental stage.

Records. Accurate records of all airplane, engine, propeller, instrument, and kindred units are extremely important to the conduct of an efficient maintenance department because they enable regular routine maintenance of the units at periodic intervals and also because the time in service furnishes the foreman with an indication of the manner in which the servicing has been accomplished. However, the main value of these records lies in the ability of the operator to present the manufacturer with accurate facts on the performance of his products, and often, with this leverage, much needed changes can be secured.



PORTABLE PROPELLER SERVICE STAND

Trouble Shooting. "Trouble shooting" describes the many varied activities of the maintenance engineer which make him a valuable asset to the operating company. In the main, the maintenance engineer takes up the slack in the relations existing between the operator and the engine, airplane, and accessory manufacturers. When operators are confronted with a recurring difficulty in any part of the plane, engine, or propeller installations, they cannot wait for the manufacturer to remedy the difficulty, but must rely on the ingenuity of their own personnel to keep the air line running. The present tendency is for the air lines to take the initiative in remedying or suggesting remedies for chronic difficulties on various pieces of equipment. This is in spite of the fact that the manufacturers have better equipment and better basic information from which to diagnose troubles. The crux of the matter is that the lines simply must have action, whereas the manufacturers are prone to take the slow, exact laboratory methods, toward which they naturally turn from their long reliance on this source in design and development work. It is sincerely hoped that some compromise may be made in this direction to permit more rapid solution of operating problems by the manufacturer in cooperation with the operators.

NAVIGATION AND FLIGHT CONTROL

Maps. Accurate maps are necessary in any navigational system. The Federal Government, through its airway sectional maps, supplies valuable aid in this direction, but many additional aids are necessary for accurate airline navigation.

Our engineering department has prepared a set of "master" sectional airway maps for our entire route. These maps show the magnetic courses and distance intervals between all adjacent points on the route, as well as the courses and distances to all fields which might be utilized in the event of bad weather. All radio-beacon stations are prominently outlined and call signals are designated. These master maps are available to the pilots for reference in preparing their personal maps in similar fashion.

We have also prepared blueprints of convenient size showing the profile, or elevation of the ground, along the route between each two adjoining points. These maps show distance intervals between significant points along the route as well as the magnetic courses to be followed. Complete information on the radio-beacon stations in the vicinity is included.

In addition, small $5^1/_2$ by 8 in. detailed maps of each field have been prepared, showing on a large scale the airport and its relation to surrounding obstructions and the nearby radio range station. All other significant data, such as magnetic variation, elevation, radio frequency, and call letter, have been included. These radio-range field maps have been made up for all fields along our route where there are existing radio range stations.

All of the aforementioned maps are furnished to each pilot and the tracings are kept up to date from day to day by the engineering department. A list of all changes is posted on the pilots' bulletin board so that maps shall be up to date at all times.

Cruising and Air-Speed Correction Charts. To enable the pilot accurately to control engine power during flight, and at the same time determine his true air speed for any given power at any altitude and temperature, the Douglas Company, after prolonged testing prepared a compact and accurate cruising chart.

By setting the Kollsman altimeter at 29.92 and correcting the pressure altitude thus obtained with the temperature correction scale provided, standard density altitude is secured. Power is determined by the propeller speed at a given density altitude. From the plot of propeller speed at density altitude, true air speed may be found by dropping vertically to a scale provided, which takes into consideration the calibration error of the air-speed installation. When the winds aloft are known, the use of this chart will readily permit the choice of the best cruising altitude.

The air-speed correction chart gives a correction of indicated to true air speed, taking into consideration the air-speed calibration error. By working backward from this chart, a recheck of the engine power, as called for on the cruising chart, may be obtained.

Navigational Log Sheets. These forms have been prepared for each section of our route and show intermediate check points between stops. The distance interval, cumulative distance each direction, and elevation for all of these points are shown on the form. Space is then provided for the pilot to enter his estimated and actual time of arrival over these points, ground speed, drift, steering course, speed data, and complete engine-power information. Provision for noting the running time on any fuel tank is made so that an accurate check of fuel consumption in flight may be taken. The use of these charts in flight has been made possible largely by the installation of the automatic pilot, which permits the pilot to devote the necessary time to navigational problems while in flight. Upon completion of the flight these log sheets are turned into the navigation-engineer's office where they are checked and graded for accuracy and completeness.

Wind and Drift Tables. In order to facilitate the choice of altitude and allow for the wind effect, complete tables have been prepared for each sector of our route, showing the speed gain or loss for a Douglas DC-2, with winds of varying intensity, arising from each point of the compass.

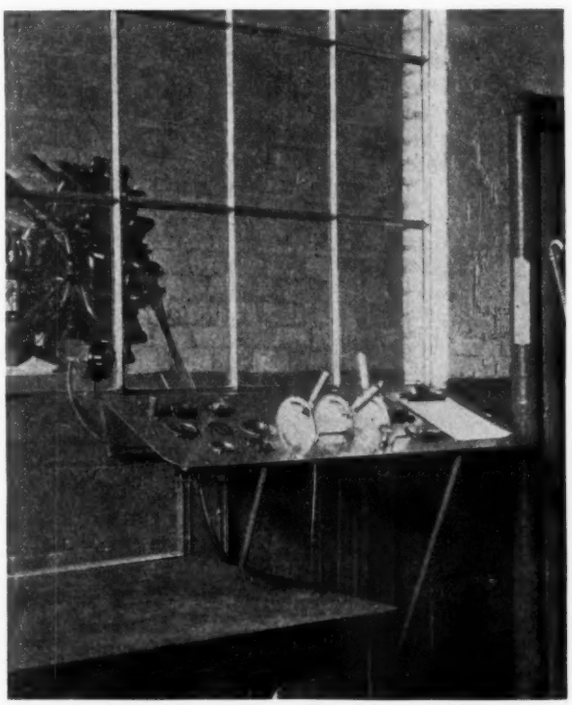
We have also prepared tables of scheduled time and speed data for each leg of our route for five different altitudes. Thus, if a pilot is flying from Kansas City to St. Louis and has decided to fly at 8000 ft because of wind and weather conditions, he can turn to these tables and find that the total distance is 229 miles, that he will cover 28 miles in climbing to 8000 ft, which will leave 201 miles at cruising speed, since experience has shown that, approximately, cruising speed will be maintained in the glide. The table shows that the scheduled time is 1:25 and that 21 min will be required to climb to 8000 ft. This means that a cruising ground speed of 184.5 mph will be required to cover the 201 miles of cruising distance in the 1:04 remaining. By consulting the wind and drift tables for the gain or loss due to the wind, the true air speed required can be obtained. The pilot may then, from the cruising chart, open the throttle to the point where the desired true air speed will be obtained at the predetermined altitude of 8000 ft.

Fuel-Duration Charts. To facilitate calculation of fuel range, a graph has been prepared on the basis of our average fuel consumption over a considerable period of time, showing the fuel consumption for various power outputs against the total gallons on board at the start of the flight. This gives a direct reading of the length of flight, in hours and minutes, which may be maintained with the given fuel load at the designated power output. This figure takes into account the Department of Commerce regulation requiring 45 min of fuel capacity to be in the tanks at time of landing.

Flight Plans. In order to consolidate all of the foregoing data in a readily usable form, we have drawn up a pilot's flight-plan form, which is filled out by the pilot, in duplicate, prior to departure. On this form the pilot shows the altitude which he has selected for each leg of his flight, and the wind and temperature at that altitude is determined from perusal of the upper-air weather reports. He then notes the drift correction required, the resulting gain or loss in speed, the cruising ground speed required to make schedule, and the corresponding true air speed required. He then shows the power which would be required to make schedule and the power which he intends using, together with the fuel consumption at this power output and the total fuel range with the fuel on board.

The estimated time of arrival at destination is noted and also the estimated remaining fuel range upon arrival. The pilot must also note alternate airports which he plans to use in the event that his original destination cannot be used, and his contemplated procedure in the case of radio failure.

The pilot then retains the original of this form and leaves a copy with the flight dispatcher. These forms are later turned into the navigation engineer's office where they are graded with the log sheets. It has been surprising to note the accuracy with which pilots can estimate the arrival time and fuel consumption after they have used these flight plans for a short time. Grades above 97 per cent are the rule rather than the exception.



ENGINE TEST—CONTROL ROOM—INSTRUMENT AND CONTROL PANEL

STATIC LOAD TEST, HORIZONTAL STABILIZER

Navigational Zipper Case. From the accumulated navigational material mentioned thus far, it will probably be wondered where, and how, the pilots manage to carry it. For this purpose we have secured a special leather brief case, with a zipper binder, in which all the material may be neatly folded and retained by a three-ring clasp. The various forms and tables are indexed and separated with stiff-backed spacers, which makes the data readily accessible. In addition each kit carries a Dalton computator for rapid calculation, a map scale, and a small drawing set. The kit completely equipped is approximately one foot square and three inches deep, which makes it easily usable in the cockpit.

Flight Control. The ground control of flight movements is now in the hands of dispatchers, all of whom are seasoned pilots with Department of Commerce instrument-flying ratings. The accuracy of flight control is considerably increased since we have started the use of the flight plan. The dispatcher through his copy of the pilot's plan, knows at all times the approximate position of the flight and the probable course the pilot will take in the event of radio failure or unfavorable weather conditions. He is also guided in many of his decisions by an operations manual, covering the recommended instrument approaches to all scheduled airports on the system, as well as the minimum weather conditions under which landings or take-offs may be attempted. All of the material contained in this manual has been examined and approved by the United States Bureau of Air Commerce.

RADIO AND COMMUNICATIONS

Design and Test of Equipment. The radio equipment now used in the Douglas transports was completely designed and tested by our radio-engineering department and subsequently built by an outside firm according to detailed drawings and specifications drawn up by this department. This enabled us to secure the type of equipment best suited for our needs, and to date we have had excellent results in service with these units.

Plane Installation. There are several unusual features of this installation worthy of mention. The main receivers and transmitters fit into machined guides on a specially constructed, shock-mounted rack. All connections are made through one or two multiple plugs so that a complete receiver or transmitter may be changed in a few moments.

In addition to our regular two-way and beacon receiver, we have a small auxiliary beacon receiver which is equipped with a separate antenna under the belly of the airplane and is designed to operate on dry cells carried in the cargo compartment. Thus we have an entirely independent reserve beacon receiver regardless of failure of the main radio power supply or antenna system.

Considerable improvement was effected in the method of remotely controlling the receivers and transmitters from the cockpit. Formerly this was accomplished mechanically, with a long flexible shaft which allowed considerable variation between the cockpit indication and the actual setting on the remote units. We now use an electric control which operates through two synchronous nonrotary autosyn motors. The characteristics of these motors are such that a movement of the rotor on one motor will be accurately followed by the rotor of the other. This type of control is light, accurate, and easy to install.

Deicing of Antennas. An important phase of the ice problem is radio failure caused by icing of the antenna. Failures are caused by the increased capacity of the antenna due to the ice covering on the wire, or grounding of the antenna to the airplane by ice bridging across the insulators. This problem has been largely solved for our radiophone communication by the use of a trailing-wire antenna, which whips around sufficiently to crack off any ice which may have formed. Unfortunately, a trailing antenna cannot be used with a beacon receiver for accurate directional indication and it is necessary to deice the conventional type of antenna. This is done by providing a shock-cord attachment between the insulator and anchor post at one end and a rubber sleeve at the insulator-to-antenna connection on the other end. When the antenna is manually pulled from within the airplane the rubber sleeve changes form and cracks off the ice that is tending to bridge the insulator. This device has proved satisfactory when used in service.

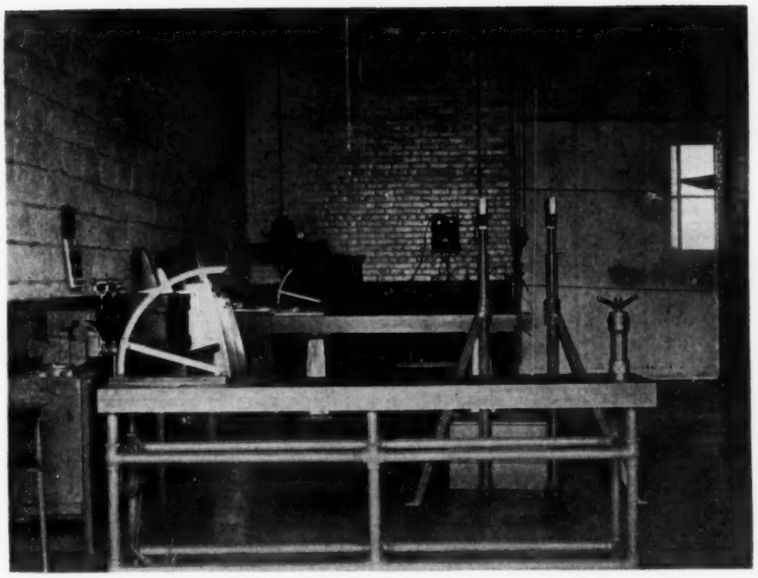
Ground Stations. The design of aircraft-radio ground stations has usually been complicated by the fact that space requirements as a rule necessitate the location of the actual equipment and antenna at a point distant from the dispatch office. This has necessitated the development of an accurate dependable remote-control system. Also the space requirements about the airport have usually precluded the use of more than one antenna and we were thus forced to develop a multifrequency antenna system. In spite of these difficulties we have been able to build up an astonishingly efficient communications system. At our Kansas City base we are daily handling an average of 700 point-to-point telegraph contacts, from 200 to 300 radiophone contacts, and from 50 to 100 messages on commercial wires.

AIRWAYS

Maintenance of Airports and Airport Facilities. In order to keep airports and airport facilities in proper condition a competent engineer is continually visiting various points of the system taking care of repair work. In many cases the airports are not the property of the air line, but are municipally owned and it is necessary to convince the local officials of the necessity of the recommended work. Usually this work is along the lines of drainage or runway improvements or perhaps changes

in the lighting arrangements. The aspirant for this job should be thoroughly conversant with civil and electrical engineering and something of the diplomat to boot.

Construction Work. In addition to the airway-maintenance work already cited, the airway engineers will be required to draw up specifications for, and supervise all construction work being undertaken by the operator.



PROPELLER INSPECTION AND ASSEMBLY SHOP

METEOROLOGY

Air-Mass Analysis. The collection and analysis of all available weather data, for subsequent dissemination to pilot personnel in the air or on the ground, is of paramount importance to air-transport operations. It is interesting to note that the air lines have pioneered the commercial application of the air-mass analysis system of weather forecasting in this country. Prior to the use of this system by the air lines, the Massachusetts Institute of Technology, California Institute of Technology, and the Navy Department had made extensive researches in this field. This system has proved accurate in service and is daily receiving wider acceptance. In addition to their work in applying the air-mass system to aircraft forecasting, our meteorological staff has conducted independent researches on such subjects as dust storms, thunder storms, and ice formation on aircraft.

RESEARCH PROJECTS

Visual Engine Synchronization Indicator. Pilots and the air-traveling public have for years been aware of the fact that the engines were for the most part not synchronized. The public merely knew that when flying in multiengined planes, they were conscious of a peculiar recurrent beat above the general din. Several years ago this was not important since the average noise level of a plane's cabin was somewhat higher than that of a boiler works. Now, however, with cabins sound-proofed so that the noise level is actually lower than that in a Pullman car, this beat became extremely annoying, and it was evident that something would have to be done about it.

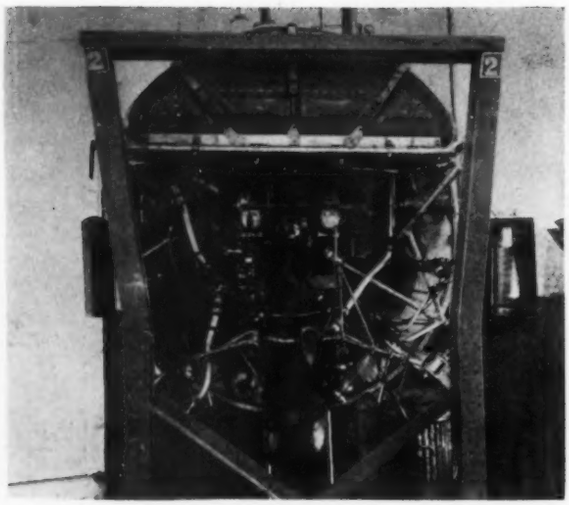
Several synchronization indicators were placed on the market, but all of them were either complicated in their installation or comparatively heavy. In an effort to secure this indication with a minimum of weight and installation difficulties our radio-engineering department conducted a number of experiments which finally led to the "synchroscope," or visual indicator, which we are now installing on all transports. In principle a lead is taken from the primary circuit of one magneto on each engine and these lead to a single condenser through a high resistance. A rectifier type of voltmeter is then placed across the condenser so as to read the voltage existing on the condenser. When the engines are synchronized there is no voltage across the condenser and the hand is still. When the engines are not synchronized the hand will pulse, the rapidity of the hand movement denoting the degree the engines are out of synchronization. Thus, in order to synchronize the engines the pilot merely has to adjust the throttles until the hand stops. The whole unit weighs only slightly more than 1 lb and requires but two wires less than 2 ft long for installation.

Instrument-Landing Experiments. Weather still continues to be the main enemy of scheduled air transport, but it is slowly being overcome through the intensive research devoted to instrument landing devices. We have been particularly interested in this subject and some time ago equipped one of our planes to fly the Department of Commerce instrument-landing system at Newark, N. J. The results were extremely gratifying from a performance angle, the only objection being the prohibitive cost of installation. We also have run tests on the Army type of instrument-landing system and expect to test this further. Following the tests of the Department of Commerce and Army systems, we installed and tested an aural instrument-approach system at our Kansas City airport. This system gave considerable promise and we have recently allocated funds to continue tests along this line which should result in a practical instrument-approach system in the near future.

High-Altitude Flight-Testing. There has been much comment lately on the advantages to be gained from high-altitude, substratosphere, flying. Unfortunately, however, there is little or no reliable information on this subject as far as passenger-carrying possibilities are concerned. In order to check this we have set aside a Douglas transport to be used exclusively as an experimental laboratory plane. With this we intend to check the actual variance from the formula generally used for estimating speed at altitude, i.e., speed at constant horsepower varies proportionately to the cube root of the reciprocal of the density ratio. To maintain our power at altitude we have now installed Cyclone engines with two-speed superchargers. To maintain our propeller efficiency as nearly constant as possible, we have installed Hamilton Standard three-bladed constant-speed propellers. At a later date we shall make tests at higher altitudes, using exhaust-driven turbo superchargers. Of course, during these flights we have been able to carry out a number of other tests on radio, engine accessories, and other units, which may be affected by altitude. To date we have been able to amass much valuable data but are not as yet in a position to draw any conclusions.

EDUCATION OF PERSONNEL

Maintenance. In order to keep our personnel up to date on all improvements and advancements in the industry, we have organized a school, with one man permanently assigned to the task of instruction and administration. All new maintenance personnel are put through a schooling for several hours



ENGINE-CHANGE ASSEMBLY JIG

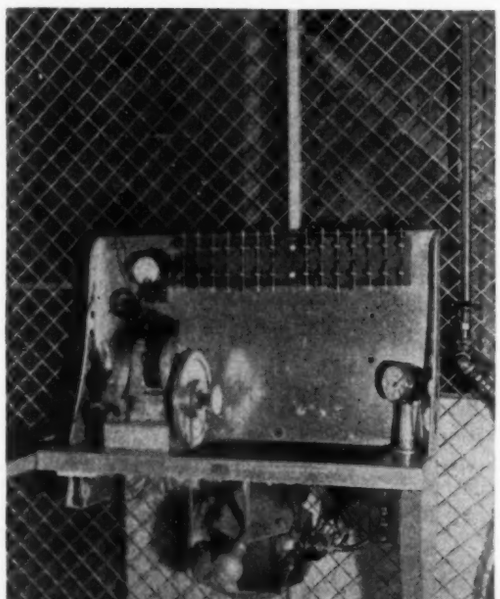
a day for a period of approximately a week. During this period they are instructed in our system of maintenance and our methods. They are also given copies of the maintenance circulars which explain in detail the operation and servicing of all our planes, engines, propellers, and other equipment, and a manual of instruction on the maintenance of Douglas DC-2 transports which we operate throughout our system. They are required to study this material and pass an examination upon it within 30 days. We also have a maintenance questionnaire which is sent once a month to all maintenance personnel. This usually contains a few brief questions, the answers to which can be found in the maintenance circulars. A record is kept of each man's grade on these questionnaires.

In addition to the required classes we also have a voluntary engine-overhaul school which meets for two hours one evening per week. Through the cooperation of the Wright Aeronautical Corporation we have obtained a complete geared Cyclone, such as we use in our Douglas planes, in a cut-away form. This school is limited to twelve in a class so that each man can take part in the disassembly and reassembly of the engine. The theory and function of the various parts of the engine are thoroughly explained by the engine-overhaul foreman, and each student is required to time the valves and the magnetos. Ever since this school has been in operation we have had a long waiting list of employees eager to take the course.

Pilots and Copilots. Before new copilots are sent out on the line they are subjected to an intensive schooling lasting about one week. During this time they familiarize themselves with maintenance and are actually taken into a plane and shown the operation of the radio, heating system, and other installational details with which they should be conversant. They receive instruction in the various accounting-department forms which they are required to handle. Weather information, operations forms, and kindred details are fully explained to them during this period, at the end of which they are required to take an examination on the subjects which have been covered.

We require all flying personnel to study the Morse code until they can pass an examination, sending and receiving eight words per minute. This is of value to the pilots in identifying radio-range call letters. Flying personnel are also required periodically to pass an examination on the Department of Commerce Aeronautics Bulletin No. 7-E, which covers the regulations relative to the operation of aircraft and licensing of flying personnel.

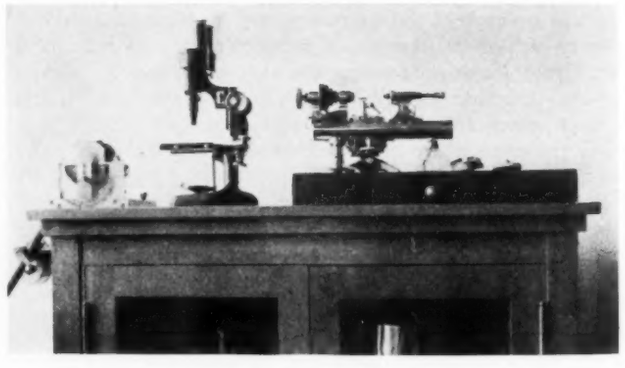
Field Managers. Once during the course of each year the field managers and head mechanics of the outside fields are rotated through the main Kansas City base for a two-week training period. During this stay, they spend time working in each of the various shops to acquaint themselves with new developments and methods which have been put into effect at the base. At the end of this period they are examined on the material covered.



MAGNETO TEST STAND

Transportation Agents. Since the transportation agents come in direct contact with the traveling public, we are arranging to have all of them spend some time at the main maintenance base so that they can receive some general instruction in our methods and control of maintenance.

Navigation Course. All pilots and copilots are kept abreast of navigational developments through the medium of mimeographed papers prepared from time to time by the navigation engineer. These papers have covered nearly all phases of aerial navigation from the rudiments of map projection, through simple drift problems, up to the specific application of navigation to the preparation of the flight-plan forms mentioned previously. Some of these papers included problems which had to be worked out and turned in to the navigation engineer.



INSTRUMENT DEPARTMENT EQUIPMENT

A BRANCH PLANT TANNERY NEAR NEWPORT, TENN., A COUNTYSEAT TOWN OF 3000 PEOPLE. IT EMPLOYS 118 MEN AND PURCHASES MATERIAL LOCALLY

INDUSTRY, AGRICULTURE, *and* POPULATION READJUSTMENT

By JOHN P. FERRIS

THE economic thinking of engineers has dealt chiefly with aspects of our economic life concerning which facts were available for analysis and interpretation. It happens that most of the statistical information we have concerning consumption and the flow of the national income is based upon figures for the country as a whole, or for states, or for individuals and corporations classed into income groups on a nation-wide basis. Comparatively little is known, for instance, concerning the *geographical* concentration of income and its effects.

Studies of the flow of money and commodities into and out of certain geographical areas indicate that the trends revealed vitally affect the operation of the entire economic system. It appears unlikely that we can enjoy national economic health until some rather fundamental adjustments are made in the geographical location of some of our actual production, irrespective of "bookkeeping" changes in the distribution of national income as between occupational groups of our population. Although some of the facts here presented were obtained in the course of studies made in the Tennessee Valley region, the problems referred to are characteristic of large areas throughout the United States and, in fact, of all industrialized nations.

Following previous depressions the revival of industry in the United States was closely related to the development of new geographical areas by people who had left the older communities. Now there are no more undeveloped areas. Again, however, it appears that the permanent revival of industry must be associated with a new development of rural areas, although the reasons are quite different. Formerly, the new regions were areas of lowest cost production for essential raw materials, and consequently they quickly developed the purchasing power needed to buy industrial goods. Today the "outlying regions" are in our rural areas everywhere—some highly productive and some relatively unproductive. The economic system has operated to drain these less productive areas of men, money, and soil fertility.

Obviously, the present cash purchasing power of the rural people is not a proper measure of the rural market for industrial products. Potentially, our 43 per cent of rural population constitutes a large part of the total market for industrial products. Industry cannot expect a reasonable revival of rural markets unless the economic trends which have operated against the rural areas are definitely and permanently reversed.

From a paper on the same subject presented at the Semi-Annual Meeting, Cincinnati, Ohio, June 19–21, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Mr. Ferris, who is connected with the Agricultural Industries Division, Tennessee Valley Authority, calls attention to the possibility of misinterpretation of the matters discussed as constituting a phase of the Tennessee Valley Authority's program. He wants it understood that the paper represents his personal observations.

Acknowledgment is made to Arthur L. Pollard upon whose original studies of county trade balances a large part of this article is based; and to R. Harold Denton for assistance in assembling the data concerning agricultural and industrial income.

ECONOMIC BALANCE BETWEEN RURAL AND INDUSTRIAL AREAS

Let us consider some facts pertaining to the economic balance between rural and industrial areas; refer to Figs. 1, 2, 3, and Table 1.

1 The purchasing power of farmers from 1909 to 1927 increased slightly, if at all, although the purchasing power of all gainfully employed persons in the United States rose sharply. The purchasing power of the entire population also rose definitely (curves II, III, and IV of Fig. 1).

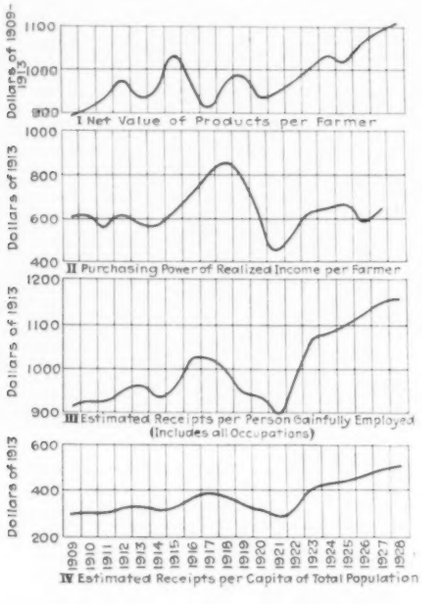

Dollars of 1909-1913
I Net Value of Products per Farmer
Dollars of 1913
II Purchasing Power of Realized Income per Farmer
III Estimated Receipts per Person Gainfully Employed (Includes all Occupations)
IV Estimated Receipts per Capita of Total Population

FIG. 1 COMPARISON: I RECEIPTS PER FARMER; II INCOME PER FARMER; III INCOME PER GAINFULLY EMPLOYED PERSON; IV INCOME PER CAPITA

(Data from "The National Income and Its Purchasing Power," by Wilford Isbell King. The term "farmer" means a resident farm operator and his family.)

The value of farm products per farmer, however, rose considerably during this same period, indicating that the farmer retained a decreasing proportion of the gross income from his products. An increasing proportion went to other groups as payments for machinery, interest, services, etc.

2 There has been a large concentration of manufacturing activities; 86 per cent of the value added by manufacturing in the United States in 1927 was concentrated in about 10 per cent of the counties of the nation.

3 No exact measure of the extent to which this concentration of manufacturing has been accompanied by geographical concentration of income is available. Commercial and financial activities and manufacturing centers tend to grow up together. Income from transportation, utilities, and professional services also tends further to concentrate income around manufacturing centers.

However, the amount of *net* income received by the people in any area bears a relation to the gross income received. In manufacturing, the total value of products constitutes a rough measure of this gross income. In agriculture the total value of crops is a similar measure of gross income. Fig. 2 (based on Table 1) shows the value of manufactured products per capita, expressed as purchasing power in 1913 dollars, for a large sample group of industrial cities, and the value of agricultural products per capita for the rural part of the population of the United States. It indicates a much higher per capita gross income to the population of these cities than to the rural population.

More significant is the fact that the trend of the past has been for the gross per capita industrial income of these centers of manufacturing to increase much faster than the gross per capita income of the rural areas increased, especially after 1910.

Both these measures of gross income are imperfect and contain considerable duplications, particularly in manufacturing. If value added by manufacture is used as a measure of gross industrial income, the conclusions are the same. It is to be noted that this measure of gross industrial income eliminates many of the duplications which arise from the classification of finished products in one industry as raw materials for another industry.

For the rural areas, however, it is impossible to eliminate duplications involved in such farmers' purchases from other farmers as grain and hay for animal feed. If these duplications could be eliminated, the disparity shown would be more marked.

Fig. 3 makes the same comparison of the trends of gross agricultural and industrial income for two groups of states: First, two prosperous states in the great Mid-West farming region, Ohio and Indiana, and second, six southeastern states (North Carolina, South Carolina, Georgia, Tennessee, Alabama, and Mississippi). Agriculture in most of the latter states is characterized by one-crop cotton farming, dependent upon world price levels. Also included is a large part of the Appalachian Mountain area in which most of the farmers live on a subsistence farming basis with very low cash incomes.

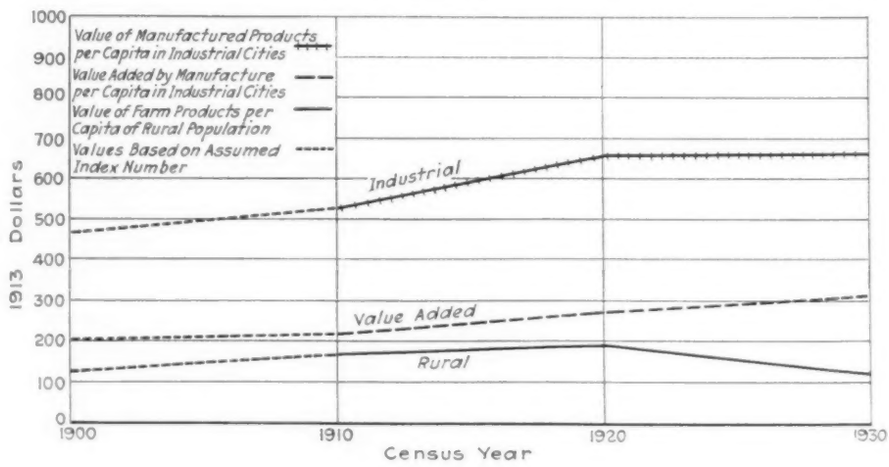

Value of Manufactured Products per Capita in Industrial Cities
Value Added by Manufacture per Capita in Industrial Cities
Value of Farm Products per Capita of Rural Population
Values Based on Assumed Index Number
Industrial
Value Added
Rural
1913 Dollars
Census Year

FIG. 2 PURCHASING POWER IN 1913 DOLLARS OF VALUE OF PRODUCTS PER CAPITA IN INDUSTRIAL AND RURAL AREAS OF THE UNITED STATES

The tendency is for per capita industrial income to outstrip per capita agricultural income under the most diverse conditions. What are the causes of this situation?

For two entire generations the proportion of our people able

to earn a living in agriculture has decreased steadily. This has been the result of technical progress in agricultural machinery, fertilizers, and improved plant species applied to agricultural production. The effective market for agricultural products has been relatively inelastic. There has been a continuous decline in the number of workers required to grow crops from 180 per thousand of the population in 1870 down to 88 per thousand in 1930. The decline continued through decades in which large quantities of agricultural products were exported. It continued during the 1920–1930 decade, in which the comparative prosperity of the cities created new demands for agricultural products.

Large numbers of workers no longer needed for agriculture were left in rural areas. There was a large "surplus" farm population and there were millions of "surplus" acres, the production from which could not be sold. (Most of this surplus was, of course, really needed by our people to support decent living standards.) The buying power of agriculture generally was lowered. Lowered income meant that rural people could not afford the things needed to make rural life attractive. Social services and schools fell below minimum standards. For half a century, a large proportion of the enterprising and effective individuals have been migrating to the cities. Finally, there was a mass migration of nearly 6,000,000 people away from the farms between 1920–1930. The driving force was the urge to earn a living, to go where there were opportunities.

Inheritance of rural property by those who had gone to the cities diverted rural income. The lower buying power of the farmer was accompanied by a proportionally higher rural debt. Again, the interest payments to financial centers on these debts drained the rural areas of their purchasing power.

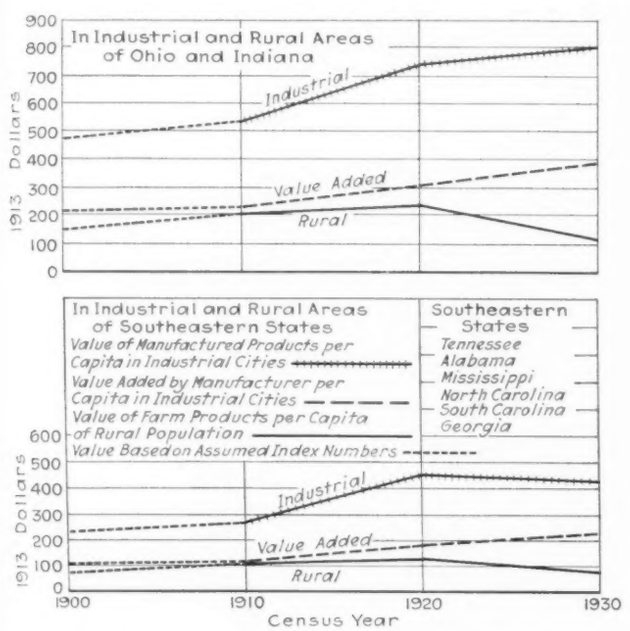


FIG. 3 PURCHASING POWER OF VALUE OF PRODUCTS PER CAPITA IN SPECIFIC STATES

The American people are distributed over this continent, and millions of them will endure very low standards of living in the environment they are accustomed to rather than change. No doubt several millions of our people would be much more productive if moved from infertile lands to fertile lands. But we do not yet know how to get large numbers of people to move from where they are to where we think they ought to live. And if they could be moved in some way, at least a generation would probably be required for them to take root in new surroundings and win their share of the national income. It is safe to say that the problem of rural income must be solved without large-scale, forced migrations of rural people.

It is quite conceivable that industry may sometime become sufficiently productive so that a comparatively small number of workers can produce in the industrial centers enough goods and service for the entire population. In that case it would be theoretically possible to pass out purchasing power to workers and nonworkers alike, the nonworkers at outlying points being maintained in complete leisure by the army of workers. But such a solution goes against common sense. We are much closer to this state of affairs than we have realized.

Under our economic system the total income of money, commodities, and services into any given area must obviously

TABLE 1 PER CAPITA VALUE OF PRODUCTS IN INDUSTRIAL AND RURAL AREAS OF THE UNITED STATES IN TERMS OF 1913-DOLLAR PURCHASING POWER, 1900–1930

Description	1930[5]	1920	1910	1900
Per capita value of products in industrial cities of the United States[a]	$1131.56	$1206.64	$500.86	$375.38
Index of prices paid by industrial group for consumption goods	170.80[1]	183.10[2]	94.50[2]	80.00[3]
Per capita value of manufactured products in terms of 1913 dollars	662.51	659.01	530.01	469.22
Per capita value added by manufacturing in industrial cities of the United States	541.28	506.32	210.72	165.10
Index of prices paid by industrial group for consumption goods	170.80[1]	183.10[2]	94.50[2]	80.00[3]
Per capita value added by manufacturing in terms of 1913 dollars	316.91	276.52	222.98	206.37
Value of farm products per capita of rural population in the United States	204.58	416.79	170.55	103.89
Index of prices paid by farmers for goods used in living	158.00[4]	210.00[4]	96.00[4]	80.00[3]
Value of farm products per capita of rural population in terms of 1913 dollars	129.48	198.47	174.03	129.86

NOTES:

[a] Industrial cities include the following: Philadelphia, Pa.; Detroit, Mich.; Boston, Mass.; Pittsburgh, Pa.; Fall River, Mass.; New Bedford, Mass.; Cleveland, Ohio; St. Louis, Mo.; Milwaukee, Wis.; Bridgeport, Conn.; New Haven, Conn.; Waterbury, Conn.; Buffalo, N. Y.; Cincinnati, Ohio; Baltimore, Md.; Worcester, Mass.; Youngstown, Ohio; Akron, Ohio; Hartford, Conn.; Minneapolis, Minn.; Rochester, N. Y.; Schenectady, N. Y.; Allentown, Pa.; Springfield, Mass.; Toledo, Ohio; Indianapolis, Ind.; Reading, Pa.; Dayton, Ohio; Birmingham, Ala.; Newark, N. J.; Jersey City, N. J.; Bayonne, N. J.; Camden, N. J.; Louisville, Ky.; Paterson, N. J.; Columbus, Ohio; Lawrence, Mass.; Lynn, Mass.; Syracuse, N.Y.; Lowell, Mass.; Pawtucket, R. I.; Canton, Ohio; Trenton, N. J.; Wilmington, Del.; Racine, Wis.; and Grand Rapids, Mich.

[1] "Cost of Living Index," compiled by Bureau of Labor Statistics, U. S. Department of Labor.

[2] "The National Income and Its Purchasing Power," W. I. King, National Bureau of Economic Research, p. 68, prices paid by urban, manual, and clerical workers for consumption goods, based on cost of living index but extended back to 1909.

[3] No "Cost of Living Index" extends back to 1900. An index of 80 has been assumed for both urban and rural classes on the basis of the retail food index of the Department of Labor.

[4] "The Agricultural Situation," Bureau of Agricultural Economics, December, 1934, p. 20.

TABLE 2 GRAINGER COUNTY, TENNESSEE,[a] BALANCE OF TRADE, 1932

	Net county income	Net county outgo
Commodities		
Sale of farm products	$425,000	.....
Purchase of food, clothing[1]	.....	$500,000
Services		
Labor, net receipts	20,000	.....
Professional services from outside	.....	25,000
Cultural and tourist[2]	10,000	.....
Financial		
Net insurance benefits and loans[3]	10,000	.....
Interest, private and county	.....	85,000
Credits and gifts[4]	22,000	.....
State Government		
Road payments received	27,000	.....
School payments received	33,000	.....
All taxes	.....	20,000
Federal Government		
Post Office expenses	24,000	.....
Post Office receipts	.....	4,000
Pensions	31,000	.....
Total	$602,000	$634,000
Total deficit	$ 32,000	.....

CAPITAL ACCOUNT

	Gain	Loss
Net Charges		
Commodity and service	.....	$ 70,000
Financial and government	$ 38,000	.....
Loans and credits	.....	25,000
Depreciation of buildings	.....	80,000
Depreciation of machinery	.....	20,000
Depletion of soil and forest	.....	55,000
Totals	$ 38,000	$250,000
Net deficit	$212,000	.....

NOTES:

[a] Grainger county, population 13,000, is exclusively agricultural, almost everything which its people obtain from the outside world being obtained in exchange for the products of its soil or forests. Grainger County has no power to tax the outside world, as do some counties which are traversed by important railroads or power lines. It has no wealth invested outside by which it can demand a share in the production made possible by such wealth.

[1] Net outside purchases include: Foods, $155,000; clothing and shoes, $140,000; automobiles and service, $120,000; soft drinks, $20,000; fertilizer, $10,000.

[2] Cultural and tourist are: Tourist receipts, $20,000; higher education, $2000; magazines and newspapers, $8000.

[3] Insurance: Benefit payments and loans, $30,000; premiums, $20,000.

[4] Credits and gifts: Credits, $15,000; gifts, $7000.

be equal to the total outgo. For a time, people in impoverished rural areas may continue to buy from the cities, but ultimately they cannot do so unless they can balance the resources flowing into each county against those flowing out.

The case study of Grainger County, Tennessee,[1] given in Table 2, shows how the income-outgo of hundreds of counties in the United States was balanced in 1932. Grainger is a purely rural county with no manufacturing and no railroad. Note that the state and Federal governments sent $91,000 of tax money into the county in excess of the tax revenue collected there. Buildings depreciated by $80,000; soil and forests were depleted by about $55,000. In that year the people of the county spent on automobiles (mostly for purchases of gasoline, oil, and supplies) $120,000. At the same time sleds were seen here and there to be replacing broken-down wagons. How long can the people of such counties continue to pay large sums to cities for gasoline and manufactured goods?

[1] Made by Arthur Pollard, Knoxville, Tenn. The data are based on estimates obtained on the ground, as there are available no real records of the transactions between one community or trade area and the outside world.

TABLE 3 McMINN COUNTY, TENNESSEE,[a] BALANCE OF TRADE, 1933

	Net county income	Net county outgo
Commodities		
Sale of farm and timber products	$ 223,000	.....
Purchase of food, clothing[1]	.....	$1,250,000
Services		
Labor outside county	130,000	.....
Industrial payrolls	1,011,000	.....
Professional services to outside	29,000	.....
Medical and dental	.....	30,000
Utility services	.....	65,000
Miscellaneous	.....	106,000
Cultural and tourist		
Churches, magazines, clubs[2]	.....	86,000
Financial		
Insurance premiums, net[3]	.....	3,000
Interest, and debt reduction[4]	.....	271,000
Taxes on public utilities	150,000	.....
Gifts, remittances, and credits[5]	41,000	.....
State Government		
Roads	41,000	.....
Schools	106,000	.....
All taxes	.....	82,000
Federal Government		
Post Office expenses, net[6]	87,000	.....
Pensions	191,000	.....
All taxes	.....	13,000
Emergency expenditures[7]	67,000	.....
Net totals	$2,076,000	$1,906,000
Gain	.....	$ 170,000

CAPITAL ACCOUNT

	Gain	Loss
Net charges		
Commodity and service	.....	$ 144,000
Financial and government	$ 314,000	.....
Depreciation, buildings	.....	74,000
Depreciation, machinery	.....	31,000
Depletion, soil and forest	.....	125,000
Totals	$ 314,000	$ 374,000
Net deficit	$ 60,000	.....

NOTES:

[a] Agriculture in McMinn County, population 29,000, is diversified and is able to profit by nearness to a large city market. Income from this source is supplemented by an even larger income from industrial payrolls, including a large railroad repair shop. Practically all the industrial products are shipped to outside markets; many of the plants are owned by outside capital. The county is unusual in that 60 per cent of the farm operators own their farms.

[1] Outside purchases include: Foods, $441,000; clothing and shoes, $329,000; automobiles and services, $225,000; hardware and furniture, $107,000.

[2] Cultural: College, etc., $37,000; churches, $24,000; tourist receipts, $6,000.

[3] Insurance: Benefits and loans, $68,000; premiums paid, $71,000.

[4] Interest and debt: All interest, $140,000; debt reductions $131,000.

[5] Gifts: Gifts, remittances from relatives, $20,000; credits, $21,000.

[6] Post Office: Expenses, $131,000; receipts, $44,000.

[7] Emergency expenditures: FERA, AAA, $20,000; RFC, HOLC credits $28,000; CCC remittances $18,000.

Another income-outgo study[1] was made of McMinn County in East Tennessee, in which a more favorable stabilization of employment and income as between urban and rural population has been achieved. Table 3 shows how the presence of industrial income has brought the income-outgo statement of the county nearly into balance.

Reference has been made to the drainage of the soil fertility of rural areas, as well as the drainage of population and money. In Grainger County it was estimated that soils and forests were depleted by about $55,000 in the year 1932. In McMinn County a somewhat closer estimate has been made, indicating the depletion of soils and forests to amount to $125,000. As crops were shipped from the county, each shipment took its toll of soil fertility, thereby eating into the fundamental agricultural capital—the land. Less plant food was returned to the soil than left it with the crops. Most income-outgo statements show only cash commodity items, ignoring impairment of the most basic of all forms of capital. If this impairment were ignored in McMinn County the statement would have shown a favorable rather than an unfavorable balance of trade.

We must face definitely the necessity in the future for an even larger proportion of our population to be employed in industry than in agriculture. There is a physical limit to the amount of food products which the population can use, even though the physical limit is considerably higher than our present level of production. On the other hand, the number of shirts we can wear and the number of automobiles we can use can increase enormously as we can increase purchasing power. The limitation on production in industry lies only in the efficiency of its organization and the effectiveness with which purchasing power is distributed to consumers.

Has there actually been a trend toward industrial decentralization?

Tracy Thompson's study, "Location of Manufacture, 1899–1929," showed that industrial expansion in the "satellite" areas around the major industrial centers has been more rapid than in the industrial centers themselves. A considerable part of these "satellite" areas is rural.

In 1925 more than 75 per cent of all manufacturing establishments in the United States were small plants using less than 100 hp each, and 22 per cent of all industrial workers were employed in such plants.

In four industries studied, L. P. Alford and J. E. Hannum[2] indicate that the most efficient plants are by no means always the largest. In the manufacturing of machine tools, for instance, plants employing only 15 to 40 men show the highest productivity. All but 5 per cent of the output of the industry in 1929 was in plants either smaller or larger than this size range; most of it was in much larger plants.

In a survey of the bread and flour industries[3] the United States Federal Trade Commission found that lowest costs of bread in wholesale baking establishments occurred in plants considerably smaller than the largest in the industry.

It is probable that the periods of agricultural prosperity in the past have rested squarely on depletion of the soil and forests. Certainly at present industry must share with agriculture the task of bringing about a proper balance of population and income as between urban and rural areas. Unless we are willing to accept a balance brought about through permanent tax payments into rural areas, or defaulted borrowing, the only way to build up rural purchasing power is to carry on a larger share of the wealth-creating industrial work at points where people on the land can work, and to let these people share both in the work and in the resulting income. The availability of electric power in hundreds of small towns and in many rural areas all over the United States and modern transportation are beginning to make such a solution possible.

Just as our agriculture sees the necessity of adjusting itself to a disappearing demand from overseas (which formerly consumed the products of some fifty million acres of American farm land), so our industry faces the necessity of rebuilding its impaired American markets.

[2] "Applications of the Kilo-Man Hour Method of Analyzing Manufacturing Operations," by L. P. Alford and J. E. Hannum.

[3] "Competition and Profits in Bread and Flour," Senate Document No. 90, 1928, 70th Congress, First Session.

A RURAL WORKMAN LAYING GOLDLEAF AT THE KINGSPORT PRESS

(This man lives five miles from the plant on a farm of his own. He is a master craftsman trained entirely by the Kingsport Press.)

CAPITALISM—THE WAY OUT FOR WHOM?

By H. A. FREEMAN

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROFESSOR SLICHTER'S[1] fundamental thesis is that stability under capitalism requires stabilization of prospects for profit. For, argues Slichter, (1) if we are to eliminate our violent cyclical fluctuations in consumers' spending, we must first stabilize business spending upon which consumers' incomes depend, and (2) stabilization of business spending is possible only if prospects for profit remain invariable. Thus, as Slichter views the situation, if we are to retain capitalism, our economic welfare will depend completely on maintaining an attractive rate of profit. Stability becomes a problem of profit stability; controlling booms means curtailing a growing rate of profit, and the problem of recovering from a depression is solved by taking steps to enhance the entrepreneur's prospects for money-making.

When depression begins, market prices fall, but costs, which are principally labor costs, hold up. Accordingly, it is no longer possible to produce and sell profitably as much as previously. Presently, in an effort to secure larger shares of the diminishing markets and thus cover fixed charges, business managers cut variable expenditures by one device or another with such gusto that the resulting decline in consumers' incomes, together with the fact that business men are able to reach the conclusion that if prices are falling, they may fall even further (the better economists call this "secondary-wave psychology")—all this, plus a point not emphasized by Slichter, that people with shrinking incomes do not spend beyond basic requirements (also generally called "psychological"), forces market prices down even faster than wages. Hence, the prospects for profit continue poor. Again, acting in admirable accord with "good" business policy, our great corporate institutions proceed to postpone replacement of raw materials, postpone repairs and improvements, pay off bank loans, pile up cash balances or balances in the form of investments in debts, while millions of workers displaced by this liquidation, to whom price declines of any magnitude soon cease to have any meaning at all, are left marooned in the middle of this "necessary" deflation. The government (i.e., the Roosevelt administration), weak in economic "law" but impressed by the spectacle of 10 million unemployed, 10 million more on subsistence wages, a modest amount of hunger and privation, growth of sweatshops, thousands of dispossessed farmers, other thousands losing their homes, savings of a lifetime lost in collapsed banks—with these results of deflation prominently visible, the government steps in and forces up consumers' incomes with such devious means as minimum-wage laws, legislation in direct or indirect support of collective bargaining, government construction, and direct relief.

All this may seem reasonably proper to half-baked social workers, but it is mixed with considerable evil for any reputable (i.e., not in Washington) economist. The latter, among the more liberal of whom the author of the book under review is a leader, remind us that action by government is inevitably taken at a time when prices are not evenly depressed, and thus, the ensuing inflation having found prices out of line, may have highly limited beneficent effects—particularly if it is applied to the wrong price level. For example, Professor Slichter explains that when the Roosevelt administration began to prop workers' incomes, agricultural prices were down 55 per cent from their 1929 level, while nonagricultural prices had fallen only 30 per cent; yet the government, through the NRA, concerned itself chiefly with the incomes of industrial workers.

Deflation was evidently not evenly balanced, and, according to economists less liberal than Slichter, we should have waited until nonagricultural prices had fallen 25 per cent more. In other words, according to the strict deflationists, we should have waited until the number of business bankruptcies caught up with the number of dispossessed farmers, during which delay, incidentally, the farmers, due to their peculiar vulnerability, would undoubtedly continue to be deflated far below the 55 per cent mark. One can hardly forbear a mental picture of the working out of this theory of uniform deflation (a theory proclaimed by many "dispassionate" economists and enunciated in many accepted textbooks): A brokerage-house-trained observer, simultaneously listening to numerous telephones bringing in the good news of the progress of deflation on the various fronts—poor-houses filled 30 per cent beyond capacity, 10,000 more debtors ruined, farmers being liquidated 500 per hour in the Midwest, big demand for stables by former home owners, small enterprises breaking bankruptcy records, 80,000 depositors getting 5 cents on the dollar, as new bank collapses keep finance in step with business—until finally, with the arrival of the moment when all price levels are evenly reduced (to zero), the advent of government assistance is heralded by the feeble applause of 100 million economically flattened but still ruggedly individualistic Americans.

Furthermore, all such kindly intervention may be fundamentally bad. In the first place, says Slichter, consumers' incomes depend on business spending. Devices for raising consumer income by other "unproductive" spending (relief payments, government construction, etc.), though temporarily useful, may produce an essentially uneconomic build-up of prices. Business leaders have retained these government-created additions to consumers' incomes simply as reserves or have used them to reduce bank loans. In the second place, government spending, government aid to labor organization, in fact, political "interference" of any kind undermines the business leader's "faith;" he can no longer be expected to "foresee" profits on the "sound" basis of agreeably low wages. Consequently, says Slichter, success in getting out of a depression does not lie in the direction of increasing consumer purchasing power. It lies primarily in the direction of larger and accelerated cuts in costs, particularly in the principal cost, labor. That is, although wages at such a time are proceeding downward at high velocity, prices are going even faster for reasons already explained. Thus, in order to open up avenues of profit, wages must be forced down even faster in order to get abreast of declining market prices. Consequently, the government, far from stopping our normal deflation, should actually bring additional pressure to bear on the level of wages, and simultaneously support the "proper" commodity markets so

[1] "Toward Stability," by Sumner H. Slichter, Henry Holt & Co., New York, 1934. 207 pp. $2.

One of a series of reviews of current economic literature affecting engineering prepared by members of the Department of Economics and Social Science, Massachusetts Institute of Technology, at the request of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

that the less intelligent producers cannot foolishly pass on this reduction in costs to the consumers in the form of lower prices. To attain these lower wages, the government should explain the advantages of flexible rates to labor unions, that is, it should exhort laborers to engage in a victorious downhill race with the price level for their own good!

Let us for a moment assume that 50,000,000 workers agree to this unique policy "for their own good." Revival sets in. But the existence of our 10 to 15 million who will emerge from the present depression unemployed is clear evidence that wages are still too high. Accordingly, when prices finally start upward, wages will lag behind as some of these unemployed are absorbed by expanding industry. Wages lagging while prices rise, the prospects for profit are even better than those which enabled business men to "foresee" the advisability of the initial expansion. This phase, during which 95 per cent of the population mark time and the remaining 5 per cent rejoice, is called a "boom," a term which must originally have come from the munitions industry. As the "boom" grows, all but several million technologically displaced workers and unemployables are absorbed. Then further industrial expansion will require wage increases. This may happen, but, as Slichter explains, if these advances are accelerated, decreased profits are in the offing. The "soundness" of recovery is undermined by the simple fact that more than 5 per cent of the people are trying to horn in on it. As costs creep up on prices, business managers try valiantly to hold on to "prosperity," but the foolish workers, egged on by trade unions persist in trying to bring the average family income up to the staggering sum of $1000 per year and thus destroy our hopes for the future. Contraction of output becomes inevitable. With wages getting high, the sensible capitalist is no longer willing to assume the "risk" of producing goods that every one needs and wants. He proceeds to curtail operations and as we head for another one- to six-year depression, "orthodox" economists once more take up the problem of explaining to the students and to the masses the subtle dialectics of the point that while prosperity is a good thing, the general public had better let it alone or it won't get any.

It seems, therefore, that our system does not operate to the apparent advantage of the majority of those concerned. Why not? The "orthodox" answer given by every nineteenth-century economist is that the price-profit mechanism, because of "disturbances," does not work perfectly. If there were no "disturbing" forces (i.e., wars, monopolies, ignorance, occasional business men who put other things above profit, political instability, inventions and so on) the price system would work admirably. That is, prices would adjust themselves instantaneously to the reduced output, the volume of consumer spending would be maintained, wages would adjust themselves overnight, and prospects for profit would continue bright. Shifts of production from unwanted to wanted goods would take place without unemployment (blacksmiths would become carburetor experts in a day) and no decline in business spending would result. Moreover, if by chance the light of profits did not shine so brightly, the demand for investment funds would decline, interest rates would fall, wages would fall—all instantaneously—profits would immediately be with us again, and all would be well. Such is the world with which our "equilibrium theorists" have been principally concerned.

But the facts are that wars happen, that monopolies exist, that governments do not last indefinitely, that the price system never did and never will work perfectly. Accordingly, Professor Slichter, in his search for means of controlling these disturbing factors uses one half of the book to rehash the pros and cons of control. For example, investment control is essential because of his point that it is variations in expenditures for plant, equipment, and inventories which cause fluctuations in business spending and thereby in consumers' incomes, while an unregulated credit mechanism lends itself easily to sharp inflation and deflation of the currency, thus affects sharply the volume of spending, and, therefore, must also be controlled. The usual means are discussed. Regulation of investments through (*a*) proper bank-reserve policy, (*b*) a capital-issues board, (*c*) taxes on high incomes, (*d*) excess-profits tax, (*e*) government spending to absorb uninvested savings are considered. The same for credit control, with (*a*) the volume of physical production as a guide to policy, (*b*) expansion of credit by government spending, (*c*) acceptance of poor risks, (*d*) the price level as a guide to credit policy, (*e*) constant volume of currency, and so on to general control through codes, the Constitution and what not. The arguments in favor of one idea turn out to be those which successfully eliminate another, and as a result Professor Slichter ends with a "program" involving unemployment reserves, selective veto for the President, a question mark on the investment problem, modified codes, control of monopolies, and changes in the Constitution, until finally, on reconsidering this chaotic structure which is to bring us "stability," the author is forced to admit the seriousness of the possibility that halfway capitalism is impossible and that when one appreciates the conditions which are necessary to the maintenance of capitalist profits, it becomes highly doubtful as to whether or not the whole system is worth retaining.

What ultimately may we state? First, that given a price-profit economy, it is probably true that the proper way to restore "prosperity" is the way of deflation of incomes. There can be little doubt that this orthodox answer, even much less liberally argued than by Slichter, is the correct one to the problem so stated, and that the adherents of currency inflation, public works, social credit, or the Townsend plan are supporting doctrines which are essentially antagonistic to the recovery of capitalist enterprise and capitalist profits. If these are the ends, the method of a more thorough deflation than that of Slichter offers the best means, and since these are the ends of many, to many deflation is the answer.

But to a few, albeit a growing number, is occurring the question, "the way out for whom?" There exists a minority, not comprised exclusively of trouble-making aliens and professional bomb throwers, which believes that such hard-won prosperity ought to have something more to offer than a subsistence income to millions of American families. There are Americans who are wondering if all is well with an economic system under which almost half the families in the United States in 1933 received incomes less than those necessary for a minimum health and decency standard. They are wondering, when we have 50,000,000 people who are able and anxious to work, and the most plenteous resources in the world on which to work, why it is necessary for someone to foresee profits in order for them to produce and consume the goods they need.

We cannot settle these wonderments easily, for they represent a class reaction to a fundamental antagonism of interests. On the one side, steadily, through prosperities and depressions, the control of American capital has and is being concentrated in the hands of a few, with an attending increase in the economic and political power of these few. On the other side, through prosperities as well as depressions, millions of hard-working families have never enjoyed even a modest share of the fruits of this capital. Both here and abroad, these two factions are breeding two representative political parties. Already each has triumphed—one in Germany and Italy, the other in Soviet Russia. In the not-too-distant future, even America may be forced to choose.

ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERODYNAMICS

Boundary-Layer Flow

IN THE flow of air past a streamline body it is known that the aerodynamic forces are closely connected with the behavior of the layer of air near the surface. The sudden changes in flow which occur when a wing stalls or a sphere passes through the critical Reynolds number are closely related to alterations of the flow in this boundary layer.

A simple account of recent developments in boundary-layer theory was required which could be related to the practical aerodynamic problems in hand. In this note the flow along a flat plate and the effect of pressure gradient on the transition of the boundary layer from laminar to turbulent and on break-away are reviewed. Finally, modern theories of the effect of turbulence and variation of Reynolds' number on maximum lift are considered. (H. B. Squire, M.A., Bureau of Scientific Research, British Air Ministry, Reports and Memoranda No. 1664, Feb. 13, 1935, 12 pp. and 15 diagrams)

AERONAUTICS

Koeller Midget Aeronautical Motor

THE development of gliders led to the appearance of a number of small motors, the purpose of which is to permit the glider to attain a certain height under its own power and thus eliminate all kinds of puller devices. When the glider has attained its elevation the motor is cut out.

Among these motors the Koeller M3 was tested and gave satisfactory results. It is an air-cooled, two-stroke cycle, opposed, two-cylinder unit. One of its notable characteristics is the fact that the ignition occurs simultaneously in both cylinders. Because of this the vibration is reduced to a minimum, in addition to which, by a proper equalization of the mass forces in the crankshaft drive, the critical revolutions are far away from the speeds used in the operation of the motor.

The two-piece crankcase is made of "electron." The drives for the magneto, fuel pump, and revolution counter are all located in a little chest cast on to the rear end of the housing. Each cylinder is equipped with its own carburetor located just ahead of the admission inlet of the cylinder. The carburetor is supplied with fuel through a diaphragm pump. The motor operates on a gasoline-oil mixture, and only the front crankshaft bearing is equipped with separate grease lubrication. No reduction between the crankshaft and the propeller is employed. The dimensions of the motor are: Bore 75 mm; stroke 72 mm; swept cylinder volume 636 cu cm; compression ratio 1 to 6.2; cruising output 16.6 hp at 2625 rpm and full output 18.5 hp at 2700 rpm; dry weight without hub 26.5 kg; fuel consumption 335 grams per hp-hr; maximum length 550 mm; maximum width 646 mm; and maximum height 324 mm. A weight of 1.4 kg per hp is not bad for a motor of this size, as, for example, the new French 26–28-hp Brissonet motor weighs 1.143 kg per hp, and the French Aubier and Dune 20-hp motor weighs 1.9 kg per hp. (Fritz Wittekind, in *Automobiltechnische Zeitschrift*, vol. 38, no. 21, Nov. 10, 1935, p. 528, 1 fig.)

Progress in Aeronautics in 1935

A SIGNIFICANT and encouraging factor in the progress that has been made in aircraft in recent years is that, with improvement in performance, economic efficiency has also been increased. Contrary to experience in the railroad and automobile industries, the operation costs per passenger mile in aircraft have decreased with advances in speed. The N.A.C.A. recognizes that the increase in speed of aircraft of approximately 100 per cent during the past few years should properly be considered as progress above normal and at a rate that cannot be sustained. Nevertheless, further material improvements are confidently expected to result from efforts already under way, including improved engine characteristics, based largely on the use of improved fuel; further fundamental investigations leading to further reductions in parasite resistance and in interference drag; improved propeller characteristics and increased propulsive efficiency; improved cowling and cooling of engines; and the placing of engines within the wings, which permits the efficient application of pusher propellers.

Of the many problems reported, the following appear to be of particular general interest:

The demand for additional engine power at altitudes has resulted in the development of multistage and multispeed geared centrifugal superchargers. Because of the higher critical altitudes at which supercharged engines are operated, it has become necessary to use intercoolers to cool the compressed air, or charge, before delivering it into the engine. An investigation is in progress to determine possible methods of increasing the cooling taking place in the intercoolers and at the same time reducing the drag of the intercoolers. A wind-tunnel investigation is being conducted to determine the heat transfer and pressure drop through a new form of intercooler that should have relatively low drag.

The investigation of the prechamber, or divided combustion chamber, has been completed. The proper shape of the cylinder clearance was determined, as well as the effect of the compression ratio and the boost pressure on the engine performance. Optimum engine performance requires that the cylinder clearance be limited to only the necessary mechanical clearance, with as much as possible of the clearance volume in the prechamber. Increase in compression ratio resulted in improved indicated performance but also increased the friction mean effective pressure. The optimum compression ratio was 15.5. Boosting improved the indicated engine performance at all loads and the net brake performance at high loads. Because the clearance volume of the prechamber head cannot be scavenged without mechanical complication, this type of combustion chamber is incapable of the high specific outputs attainable by other less restrictive types, notably the displacer-piston combustion chamber.

Technical Note No. 514, describing the effect of combustion-chamber shape on engine performance, has been pub-

lished and a technical report summarizing all previous work is being prepared to conclude this investigation.

Of four aluminum - alloy propeller blades examined during the year, two had failed in service, one during the test flight of a new airplane, and the other during an engine test on a test block. Both failed as the result of a fatigue fracture at the hub. The examination of two other blades was prompted by the belief by the maintenance personnel that the peculiar grain structure and marked contrast in grain size exhibited on the surfaces of the blade was an indication of defective material. No evidence that such was the case was found.

Numerous rotating-beam fatigue tests have been made on specimens machined from hollow welded-steel blades; some new, some used but without failure, and one blade that had failed in service as the result of fatigue. The endurance limit has been determined on specimens from the basis steel (S.A.E. 6130) where it was not affected by the welding operation; on specimens consisting mostly of weld metal; on specimens consisting partly of weld metal and partly of basis steel and containing defects detected by the magnetic-dust inspection method; and on specimens containing surface defects similar to those found on the blades, some of which are apparently unavoidable. Blades are now being plated with chromium by some makers to provide resistance to surface corrosion and abrasion, and fatigue tests to obtain information on the possible effect of the chromium coating on the fatigue limit of the steel are necessary. No important conclusions can as yet be stated on the basis of the results. (Twenty-First Annual Report of the National Advisory Committee for Aeronautics, 1935, Administrative Report Without Technical Reports, 44 pp.)

AIR CONDITIONING

Air Conditioning of Motor Vehicles

A DESCRIPTION of a new system developed especially for buses, but applicable with modifications to private cars, taxi cabs, and ambulances.

The system for vehicle air conditioning utilizes a low-pressure refrigerating compressor having no reciprocating and very few moving parts. The power for the compressor is low and is supplied by the bus or car engine. The compressor supplies the refrigerant to the cooling unit or evaporator located within the bus. A small motor-driven fan draws the air from the vehicle over the evaporator and circulates it within the vehicle's interior, while at the same time drawing in an adequate amount of outside air to provide proper ventilation at all times. The liquid refrigerant, while passing through the cooling coils, where it extracts heat and dehumidifies the air, is converted from a liquid to a vapor. The vapor is then cooled in an air-cooled condenser unit which is mounted outside the passenger compartment so that the movement of the vehicle provides the required passage of air over the condenser coils. The refrigerant vapor thus condensed and cooled, having given up its heat to the outside atmosphere, is returned to a liquid receiver and the refrigerating cycle is repeated.

The matters of distribution of the conditioned air in the bus and the size and capacity of the air-conditioning apparatus are discussed in the original article. The system here referred to has been developed jointly by the Houde Engineering Corporation of Buffalo and the Carrier Engineering Corporation of Chicago. (*Heating and Ventilating*, vol. 32, no. 11, November, 1935, pp. 23–24, 2 figs.)

Unit Cooler and Heat Pump

THE cooling system of an air-conditioning plant may be used in reverse for heating on moderately cold days. A forced-draft unit cooler is capable of being applied in this dual function.

It is possible to obtain several times as much heat out of a refrigeration machine as the heat equivalent of the electrical energy consumed by the motor. The theoretical ratio between the heat output from the unit to the heat equivalent of electrical energy of the motor may be as high as 11 to 1 for the heating portion of the refrigeration system, namely, the condenser, and 10 to 1 for the cooling portion of the system, namely, the evaporator. This theoretical consideration of the reversed Carnot cycle was covered in the paper by A. R. Stevenson, Jr., in the February, 1932, issue of *Refrigerating Engineering*, and had previously been given consideration by Lord Kelvin, C. P. Steinmetz, and others.

The author considers as a typical case a 10-hp condensing unit and then proceeds to outline a means for utilizing a unit cooler alternately for heating and cooling of a room. A similar unit placed in a penthouse on the roof is in effect a condenser when the unit in the room functions as an evaporator, and the unit on the roof acts as an evaporator when the unit in the room functions as a condenser.

The complete installation consists of a motor, a compressor, receiver, high- and low-pressure control, in the basement; and a forced-draft unit cooler in the room and another one on the roof. Each of these units is connected to a thermostatic expansion valve. The details of the installation are given in the original article. (J. Askin, Fedders Mfg. Co., Buffalo, N. Y., in *Refrigerating Engineering*, vol. 30, no. 2, August, 1935, pp. 72–74, 4 figs.)

APPLIED MECHANICS

A Distribution Method of Stress Analysis

SCANT attention has been given in Great Britain to a method of determining the stresses in framework, described some years ago by Prof. Hardy Cross, which should be of considerable use to aeronautical engineers.

Cross illustrated his method of analysis by determining the bending moments in rectangular building frames with perfectly stiff joints so constrained that no translation of the joints was possible. The better known methods of dealing with this problem, such as slope deflection or minimum strain energy, imagine the structure cut at such sections as would make it simple, stiff, and necessitate the solution of equations which set out the relations between the angles through which the cut ends must turn, or the reactions necessary to bring about these rotations, to make the structure continuous again. The Cross method, however, not only keeps the joints stiff but, in the first place, fixes them in space so that the structure can be considered as made up of members encastered at their ends. The application of the external load system produces end moments in the members and produces also an external moment at each joint since it is fixed in space. One joint is then released, that is to say, the external moment is removed and the joint is no longer in equilibrium. It immediately rotates until a new equilibrium position is reached, and in so doing modifies the end moments in the adjoining members. This joint is now fixed again in its new position and another joint is released which moves into a new equilibrium position, further modifying the end moments.

This distribution method appears to be complicated but when a number of examples have been worked out and the physical significance of the various steps grasped, the full simplicity of the method will be appreciated. It has one great advantage over the more usual methods in

that simultaneous equations, apart from the groups of three used in determining the various factors, are avoided and the behavior of the frame under any load system can be visualized at every stage. The investigator is thus able, with confidence, to make slight alterations in the normal procedure to suit particular cases. He is able to carry his work to any desired degree of accuracy and is not tempted, as in other methods, to make simplifying approximations the full significance of which cannot be gaged.

While the distribution method can be used on a highly redundant structure without considerable labor it enables a solution to be obtained in many cases where other methods are impossible. (J. F. Baker and A. J. Ocklestone, British Air Ministry, Reports and Memoranda No. 1667, March 30, 1935, 82 pp. and 42 diagrams)

INTERNAL-COMBUSTION ENGINEERING

Tests With Gasoline Injection and Spark-Plug Ignition in a Diesel Motor

THESE tests were carried out on a second-hand six-cylinder precombustion-chamber Diesel vehicle motor of 7.07-liter capacity. The compression ratio was reduced from 17.0 to 6.05 by the interposition of a pad between the cylinder head and the block. The fuel-injection pressure was set at 75 atm, a Bosch fuel pump being used. As a fuel, Bevaulin was used with an addition of 0.5 per cent lubricating oil. The details of the tests are given in the original article. At part load the air admission had to be reduced in order to obtain the best results. The conclusions to which the author arrives are as follows:

1 The injection must occur very early before the end of the exhaust stroke in order to obtain the highest output and the best utilization of heat. It seems that as much heat and time as possible should be available for the complete vaporization of the fuel before the ignition.

2 An injection pressure of only 25 atm was finally found to be necessary, because, obviously, the high temperature obtaining in the cylinder at the instant of beginning of injection and at the end of the exhaust stroke will be sufficient even with moderate mechanical atomization to vaporize the fuel.

3 It is notable that with a comparatively high compression ratio of 6.05 there was no tendency to knock with Bevaulin as a fuel, and it seems likely that this is due to good vaporization of the fuel previous to ignition. (Bevaulin appears to be a trade name for a gasoline.)

4 What the effect of the presence of the precombustion chamber on the process here tested has been could not be very well established as all the tests were carried on with the motor equipped with the precombustion chamber. However, because of the increase of the regular compression chamber for the purpose of reducing the compression ratio, the share of the precombustion chamber must have been comparatively small. (P. Langer and H. Vüllers in *Automobiltechnische Zeitschrift*, vol. 38, no. 19, Oct. 10, 1935, pp. 471–472, 4 figs.)

Air-Fuel Ratio on Fuel Spray and Flame Formation in a Compression-Ignition Engine

ONE of the advantages of the compression-ignition engine is that as the fuel quantity injected into the combustion chamber is decreased the air quantity inducted can remain constant so that the fuel is burned with a large excess of air. As a result, the combustion efficiency of the engine increases as the air-fuel ratio is increased. As the combustion efficiency increases the mechanical efficiency decreases; therefore, the overall efficiency tends to remain constant. It is this fact that causes the fuel-consumption curve of the compression-ignition engine to show so little change for a wide range of load conditions.

Tests on compression-ignition engines have shown the fuel to autoignite with an estimated air-fuel ratio of about 1000. In practice, an engine will use ratios as high as 70 to 80. Although the fuel is undoubtedly stratified at the high ratios so that the actual ratio in the combustible mixture is considerably lower, no information has been obtained on the extent of the stratification. Data on the stratification of the fuel may be obtained by exploring the combustion chamber with a gas-sampling valve such as that developed by Spanogle and Buckley. High-speed motion pictures may be taken of the fuel spray and flame formation under conditions of varying air-fuel ratio. The present report discusses the results of tests made during the latter part of 1934 in which the motion-picture method was used. These tests are part of a general program of research on combustion in a compression-ignition engine being conducted with the N.A.C.A. combustion apparatus.

When considering the effect of air-fuel ratio on the thermal efficiency of the engine, two factors must be considered the combustion efficiency and the cycle efficiency. It must also be remembered that there are two fluids entering into the chemical reaction, the fuel and the air. In order to obtain the maximum and most efficient heat input both fluids must be completely utilized. With the present knowledge of methods of distributing the fuel in a combustion chamber, either fluid can be completely utilized only at the expense of an excess of the other. Of course,in a practice the air is present in excess because a low specific fuel consumption is more important than a low specific air consumption.

The results presented show that definite stratification of the fuel charge does occur in the combustion chamber of the compression-ignition engine even though moderate air flow exists. The start of burning relative to the fuel sprays is not affected by the air-fuel ratio, nor is the rate of flame spread greatly affected by the ratio.

The results at the higher ratios showed that the rate of diffusion of the gases in the combustion chamber, as indicated by the flame spread after the maximum pressure has been reached, was relatively slow. This result in itself indicates why it is difficult to obtain a good mixture of the air and fuel in the combustion chamber of a compression-ignition engine. (A. M. Rothrock and C. D. Waldron, National Advisory Committee for Aeronautics Report No. 545, 1935, 9 pp., 9 figs.)

LUBRICATION

Synthetic Lubricants

BECAUSE of the fact that the major part of mineral lubricating oils has to be imported by Germany from abroad, much attention has been devoted there to the production of synthetic oils. One of the possible solutions of this problem is represented by the kogasin process perfected at the Kaiser-Wilhelm-Institute for Coal Research in Mulheim-Ruhr by Franz Fischer and Hans Tropsch who incidentally have recently completed a process for the synthesis of gasoline at atmospheric pressure.

The simplest and apparently most accessible way for the production of lubricating oils consists in the polymerization of unsaturated hydrocarbons, which means olefines. Another attractive possibility lies in the transformation of saturated hydrocarbons, that is, paraffins Kogasin represents a mixture of saturated and unsaturated aliphatic hydrocarbons. The unsaturated hydrocarbons which differ from the corresponding paraffins

TABLE 1 PROPERTIES OF VARIOUS KOGASIN OILS AS COMPARED WITH A HIGH-GRADE MOTOR-VEHICLE OIL ON THE MARKET

	1 Winter oil	2 Summer oil	3 Aero oil	Commercial oil
Specific weight at 20 C, g per cu cm	0.838	0.850	0.854	0.882
Viscosity at 20 C, deg Engler	32.00	75.8	123.5	32.60
Viscosity at 50 C, deg Engler	6.06	12.3	17.5	6.10
Viscosity pole height, V_p	2.13	1.99	2.15	2.15
Flash point in open vessel, C	205	262	282	220
Cold pour, C	−42	−37	−30	−16

by the fact that they contain one molecule of hydrogen less and may be designated as mono-olefines, are compounds possessing a high tendency toward transformation. The ratios between the amounts of saturated and unsaturated hydrocarbons in the products of synthesis may be controlled within wide limits by a proper selection of process detail, particularly by varying the composition of synthetic gases.

In order to obtain as large an output of lubricating oils as possible it is desirable to make the content of mono-olefines as great as possible. From this point of view it may be said that kogasin obtained from water gas with a ratio of carbon monoxide to water as 1:1 is a particularly suitable raw material for the manufacture of lubricating oils, as it contains about 50 per cent by weight of olefines capable of undergoing the desired reaction.

As regards the catalysts, the transformation of the unsaturated hydrocarbons to viscous oils occurs with aluminum chloride though other materials may also be used as catalysts. Particular attention must be paid to prevent excessive heating of the mixture by the heat liberated in the course of the reaction. In commercial operation the process is so conducted that a kogasin fraction containing an appropriate amount of olefines is rapidly treated with 2.5 to 5 per cent of aluminum chloride (these percentages are by weight of the olefine to be treated). An excessive heating of the mixture is prevented by a gradual addition of the catalyst. It has been found that a reaction temperature of the order of 100 C gives the best results and that the conversion is completed in about eight hours. The material obtained as a result of the reaction consists, in addition to the lubricating oils, of unconcerted paraffin hydrocarbons, the aluminum chloride depositing out of the mass by itself. In order to remove floating particles of tar the mixture of hydrocarbons is treated by a small amount of contact clay and then subjected to distillation. After the low-boiling hydrocarbons consisting mostly of paraffins have been distilled at atmospheric pressure, a further decomposition takes place at partial vacuum. The distillation is carried on as long as lubricating oil of the desired viscosity is present in the mixture. It is not necessary to distill the lubricating oils, although it may be desirable to do so under certain conditions.

PROPERTIES OF KOGASIN LUBRICATING OIL

Viscosity. If it is desired to obtain a high-grade lubricating oil it is far from immaterial what olefines or olefine mixtures are submitted to polymerization, and it has been found that the size of the molecule of the unsaturated hydrocarbons has a material influence on the viscosity characteristics of the resultant lubricating oil. Other properties being equal, the value of a lubricating oil increases with the flatness of its viscosity-temperature curve. Taking the lubricating oils obtained from natural petroleum it is found that the so-called paraffin-base oils, such as the Pennsylvania oils, are characterized by a desirable shape of their viscosity-temperature curve with a "pole height" (according to L. Ubbelohde) of 1.9. On the other hand the so-called asphalt-base lubricating oils, with a pole height of about 3.7, lose a comparatively large share of their viscosity when subjected to a rise of temperature.

When these considerations are applied to kogasin oils it is found that the fractions containing olefines and lying in the region of boiling from 125 to 250 C are particularly suited for conversion into lubricating oils. It is said that the oils produced from these fractions are equivalent to the best Pennsylvania oils in the matter of viscosity. Moreover, the synthetic oils are superior to all known natural lubricants because of certain valuable characteristics which they are said to possess. The specific weight is unusually low and amounts to only from 0.84 to 0.85 due to the high hydrogen content of the oil (14.2 per cent). With this goes the low tendency of these oils to carbon formation on combustion in the cylinder of an engine, the Conradson number being practically zero.

Other Properties. The cold-pour number of these kogasin lubricating oils is remarkably low (—30 C and less). The oils also have a remarkable capacity for resistance against oxidation effects of various kinds and show practically no presence of asphalt compounds. Table 1 gives detailed figures for kogasin lubricating oils and, for the sake of comparison, a well-known commercial motor-vehicle lubricant.

Like all other products of synthesis, kogasin lubricating oils contain no sulphur. This makes it possible, when a special oil is desired, to produce it by a subsequent mild hydrogenation process. The oils so obtained are perfectly colorless and show a practically unlimited ability to resist the effects of exposure to atmospheric oxygen and light. These special oils may be profitably employed in installations where even a slight sludging is to be avoided.

Productivity of the Process. As regards the productivity of the process of manufacture of kogasin lubricating oils it is stated that the polymerization as practiced by the authors produces a conversion of about 60 per cent by weight of olefines into viscous oils. It is expected, however, that this figure will be improved. The other 40 per cent is not lost and either remains unconverted or, a major part is converted into oils that have a comparatively low viscosity which may be combined with the gas-oil fraction.

The amounts of lubricating oils obtainable from kogasin may be materially increased should this become necessary. This can be done, as has been pointed out by F. Homann, on the basis of his experimental work at the Kaiser Wilhelm Institute for Rheology in Göttingen, by using paraffin hydrocarbons for the production of lubricating oils. In this process the kogasin fraction with a boiling point of above 200 C, freed from solid paraffin held in solution, is then chlorinated by gaseous chloride to such an extent that on an average two atoms of hydrogen in the hydrocarbon molecule are replaced by chlorine. The chlorinated product thus obtained is then contacted with aluminum chloride or activated aluminum until all the chlorine has been removed and the kogasin converted into a lubricating oil. These kogasin lubricating oils have also a flat viscosity-temperature curve corresponding to a pole height of 1.7 to 1.8. Their cold-pour test and resistance against oxidation are also very good. (Herbert Koch, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 80, no. 2, Jan. 11, 1936, pp. 49–51)

MACHINE-SHOP PRACTICE

Methods of Joining of Materials Used in Strong, Light Structures

THIS problem appears to be of particular importance in the design of rigid airships because a great resistance to loads must be there provided with a comparatively low weight of materials. Almost the only work so far published on the fatigue behavior of structures has been carried out by the Deutsche Versuchsanstalt für Luftfahrt. The experiments reviewed in this paper were made on wing spars for airplanes and the paper describes in detail how the loading on the spars was obtained and how the spars behaved under the load.

The first steel spar failed under a small alternating load, the fatigue crack starting at a rivet hole. The next spar tested was therefore loaded much less and in such a manner that there should be little reversal of stress, that is, the dynamic load acting together with the static load caused variations in stress from a small value in tension (near zero) to a larger value in tension. When the specimen broke the failure occurred at the spot weld next to the most highly loaded section.

The load variation in this latter experiment corresponds very nearly to the application of a repeated load without reversal. From this the relation between the endurance of the structure for this type of dynamic loading to the ultimate strength of the material is dynamic load (σ_D) = 0.15 ultimate strength σ_z.

The fatigue crack, shown in a photograph in the original article, at the beginning passed through the edge of the spot weld. This makes it important that the fatigue properties of the material in the condition that exists near a spot weld be thoroughly investigated. This is discussed in greater detail in the original article.

Another box spar made of the same material and with the same type of structure, except that it was joined by rivets, was tested. It failed after 700,000 applications of a load which varied from +15.5 kg per sq mm to —12.3 kg per sq mm, or at almost completely reversed loading, at a point on the spar not in the overhang.

In this case the endurance limit σ_D = 0.125 σ_z of the ultimate strength. The failure started from a rivet hole and spread to other rivet holes, as is seen in Fig. 3 in the original article.

Further experiments were undertaken with four lattice-type spars made of steel and joined by rivets. The ultimate strength of the material in this case was 75 kg per sq mm. Three of these spars failed in fatigue, in which the fatigue crack started from a rivet hole. The fourth spar had been loaded with a static load before the endurance test in such a manner that slight buckling occurred in one of the members. This latter spar failed in fatigue within the same limits of stress variation as the other spars; however, in this case the fatigue crack started at a point that had previously been buckled.

The best spar was subjected to reversal of stress from —4.7 to +4.5 kg per sq mm, and failed after the relatively high value of 2.29×10^6 reversals, while the poorest spar failed after but 460,000 reversals with no static load and a dynamic loading of ±2.4 kg per sq mm. The relation, then between

$$\frac{\text{endurance strength } (\sigma_D) \text{ of the spar}}{\text{ultimate strength of the material } (\sigma_z)}$$

varied between $\sigma_D = 0.032\ \sigma_z$ and $\sigma_D = 0.061\ \sigma_z$.

Wooden spars similarly tested most nearly approached the fatigue limit of the material from which they were made. This is, of course, largely due to the fact that the parts of the spars were joined by gluing, and joining in this manner avoided stress concentrations.

The tests reviewed here show that, with but one exception, the fatigue cracks started at points of stress concentration, that is at the rivet holes or in the region near the spot weld. The exception to this was the case of the spar previously buckled in a static test.

The difficulty lies, perhaps, first of all in the nature of fatigue behavior. A specimen may fail in fatigue at stresses so small that there is no yielding of the material. This means, of course, that "the cleverness of the material" cannot come into play in order to prevent stress concentrations, as it can and does in static loading. By this "cleverness of the material" is meant its ability to yield plastically after a certain limiting load has been exceeded. In a riveted joint, for example, one of the rivets may have been so formed that it bears an unexpectedly large load. If the whole joint is loaded statically, yielding of the material will occur first at this rivet, and this yielding will then aid in distributing the load to the other rivets, thus avoiding uncontemplated high stress peaks.

But these conditions do not apply to dynamic loading and it appears necessary, therefore, at least not to exceed the fatigue limit of the material with the stress-concentrations expected at a rivet hole or near a spot weld.

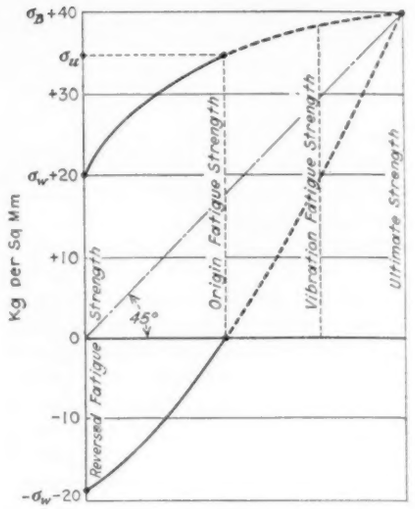


FIG. 1 SCHEMATIC FATIGUE DIAGRAM ILLUSTRATING THE VARIOUS TYPES OF FATIGUE STRESS AND THEIR LIMITATIONS

For making a more complete analysis of the behavior of solids subject to static and varying loads, the author refers to a mechanical model recently proposed by W. Spaeth, by means of which Spaeth has been able to reproduce theoretically all of the phenomena connected with the mechanical behavior of solids.

Among the matters investigated by this process is that of improvement of the properties of the material by working. The author finds that the external load is therefore by no means a measure of the forces acting in the material. Since, however, during the course of static, and some types of dynamic, loading, the angle Φ decreases (ordinarily observed through the decrease in the damping capacity), it may be seen that during the course of an experiment the forces acting in the springs of the Spaeth model decrease. If the initial load is not too great and does not harm the elastic properties of the springs, then as the angle decreases the external load may be increased without overloading the springs. In other words, the external properties of the material increase because of the previous application of load. This phenomenon accounts for the improvement in strength properties during the static and endurance tests, and has frequently been observed.

From this discussion it is seen that a quantity of real importance in judging the properties of a material, and one of great importance to the designer, is the strength of the springs in the Spaeth model, that is, the natural elastic limit for the fatigue strength as determined experimentally.

The next subject considered is that of

fatigue properties, or what is called the natural elastic limit, of the material in the atmosphere.

In Fig. 1 it is shown how the fatigue strength varies with the type of loading. These curves have been partially determined for a carbon steel. The abscissa indicates the static loading, and the enclosed triangular area the allowable limits of variation of the combined static and dynamic load. Three main types of simple fatigue are differentiated here. At the left, where the total load is variable and is completely reversed, it is called the "reversed fatigue strength," and is indicated by σ_w. The next type of fatigue is that in which the load varies from zero to some positive value. This is called the "origin fatigue strength" and is indicated by σ_u. Further, toward the right in the diagram, the condition is indicated in which a small variable load is superimposed upon a static load. This is called the "vibration fatigue strength" and is indicated by σ_v. It is seen that small variable loads may be superimposed upon a static load in such a way that under certain conditions the total load may be almost equal to the ultimate strength. And, finally, at the extreme right of the diagram (where there is no variable load), the static strength is indicated.

The author believes that while such investigations require a long time and much effort, a knowledge of the complete diagram is of importance in the design of strong, light structures. He examines these fatigue diagrams from the standpoint of the Spaeth model. The fatigue diagrams, of which an example is shown in Fig. 2, appear somewhat unusual in that, as the static load is increased, there is still a decreasing small variable load permitted within safe limits of the material, so that the total additive load is increased. The model of Spaeth suggests an explanation for this.

In making these approximate diagrams, the length of the abscissa is made proportional to the ultimate strength, and on the right-hand end of this line, another line of equal length is erected. On the left-hand end of the abscissa (where the static load is zero), a line is drawn above and below the abscissa, of a length proportional to the reversed fatigue strength of the material. Three straight lines are then drawn, connecting the plus value, the minus value, and the middle (zero) of the reversed fatigue strength with the point corresponding to the value of the ultimate strength.

In this connection the author believes that short-time fatigue tests do not yield the accurate results that the long-time tests do, but may be used within certain practical limits.

Among the other subjects that are discussed in the article may be mentioned corrosion fatigue, the influence of notches on the fatigue properties, the aftereffect or the creep, the damping in the region below the natural elastic limit, heat-treatment, and the effect of occasional

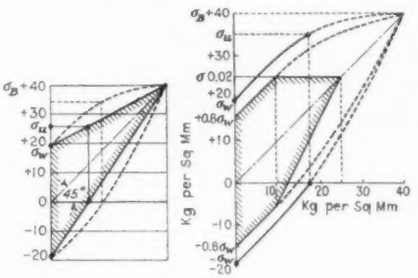


FIG. 2 (LEFT) A FATIGUE DIAGRAM FOR A GERMAN ALUMINUM ALLOY WITH PERMISSIBLE STRESS LIMITATIONS FOR BOTH STATIC AND DYNAMIC LOADING DRAWN IN

FIG. 2 (RIGHT) A METHOD FOR APPROXIMATING A FATIGUE DIAGRAM FROM A KNOWLEDGE OF FATIGUE LIMIT IN REVERSED BENDING AND OF THE ULTIMATE STRENGTH

overstresses of short duration. Of the two methods of welding, namely, electric spot welding and seam welding, the author gives preference to the latter. Because of the general interest in the subject of creep the following is cited from the original article.

Theoretical considerations from the Spaeth model show that even at stresses below the natural elastic limit a certain amount of afterlengthening, or creep, is to be expected. It is seen, furthermore, that this creep is by no means harmful to the material itself, although in certain conditions it might be harmful to a complete assembly. This natural creep is to be regarded as nothing more than the action of the material in adjusting itself to the conditions of the load, and will finally come to a standstill, and actually results in an improvement of the strength properties of the material.

Rivets are usually squeezed in place in making riveted joints in the light alloys. Such squeezed rivets exert a radial force on the material around the rivet hole, and in this way change the direction and magnitude of the stress concentrations that would normally occur near a hole in the material under stress. Such properly squeezed rivets therefore improve the strength properties of the joint over what might be expected. However, if the material creeps to some extent at temperatures to which the joint is exposed, the stresses in the material due to the squeezed rivet may be relaxed in the course of time, and the beneficial effect of the squeezed rivet decreased or lost. It would seem, therefore, that studies of the creep of materials at temperatures to which the joints will be exposed (atmospheric temperatures), would be of value. (Raymond H. Hobrock, in Report on Airship Forum, Daniel Guggenheim Airship Institute, Publication No. 3, 1935, original article pp. 64–84 and discussion pp. 84–88, 16 figs. in original article and one in the discussion)

POWER-PLANT ENGINEERING

First Thermal-Electric Power Station in England

REFERENCE has been previously made to this proposed installation in which the generating station is expected to operate at 60 per cent efficiency by selling power and steam for process and factory heating. This installation is known as the Worksop scheme.

It is proposed to acquire an area of 750 acres adjoining the Manton colliery just outside of Worksop, where it is proposed to establish a station and such individual firms as may be induced to come. In the Manton colliery there exists an underground river involving the pumping out of more than 4,000,000 gal of water daily going to waste. It is proposed to obtain from this source all water required both for the station and the factories.

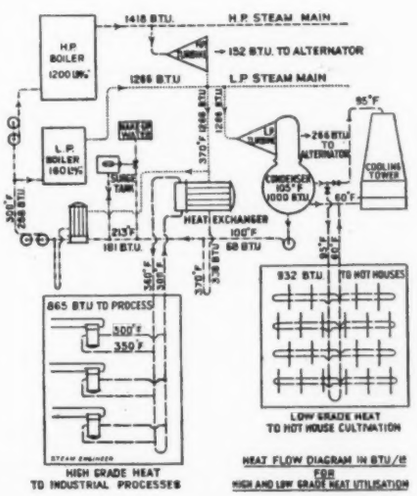


FIG. 3 HEAT-FLOW DIAGRAM SHOWING THE APPROXIMATE BTU REQUIRED FOR POWER GENERATION AND THE AMOUNT PASSING TO PROCESS

Fig. 3 shows the heat-flow diagram. The main steam will be generated at 1200 lb per sq in. pressure. It goes directly to the high-pressure turbo-generator which it leaves at a pressure of 150 lb per sq in. Here the steam line is divided, some of the steam going to the low-pressure turbine set, and some to the heat exchanger. To supplement steam supply, for process, a low-pressure boiler is to be installed to generate steam at a pressure of 160 lb per sq in. This boiler will be automatically controlled in accordance with the demand which exists for steam.

The plant will operate under a closed feed system and a reheat cycle for the steam from the high-pressure turbine. There will be a main heat exchanger and each factory will have its own heat exchanger designed for its specific pressures and temperatures. The water in the heat exchanger will be pumped under pressure to the various factories, the temperature of the outgoing water being estimated at 360 F and the return water at 300 F. On the low-pressure side of the plant it is intended to cater for the market gardener requiring heat for hothouse cultivation and supply it with the cooling water that is required for the condenser on the low-pressure turbine.

It is expected that with a load factor of 50 per cent or over, heat will be sold to the consumer at the rate of 1.5 pence per therm (100,000 Btu). The success of the scheme obviously depends on the establishment of a sufficient number of enterprises taking power and heat. (The *Steam Engineer*, vol. 5, no. 50, November, 1935, pp. 49–51, 2 figs.)

MacKirdy System of Power Generation

THE MacKirdy system of power generation has been evolved by William MacKirdy, of Montreal, and employs a mixture of the combustion gases from oil fuel with steam in order to maintain a workable temperature, the energy from the expansion of the mixed fluid being used in a specially designed piston engine.

In tests a small unit of 60 bhp developed its full load at 750 rpm over a period of $2^1/_2$ hr, consuming 61 lb of fuel oil (19,000 Btu per lb) which is about 0.4 lb per bhp. Better results are expected from the new unit. In this the generator for 250 bhp is spherical in form and measures only 16 in. outside diameter. It generates a mixed working fluid at 400 lb per sq in. The engine runs at 750 rpm.

A sectional view of the generator is shown in Fig. 4. It has a central cylindrical combustion chamber varying in diameter on different horizontal planes. The oil fuel and air enter on the top of the combustion chamber, starting being effected by means of an electric filament. At the bottom of the combustion chamber is a water nozzle and the fine jets of water heat the combustion gases issuing at high velocity from the combustion chamber. The mixture is forced around the annular space to the outlet marked "power." The air and oil are delivered to the generator at about 405 lb per sq in. A two-cylinder engine is illustrated in Fig. 2 in the original article.

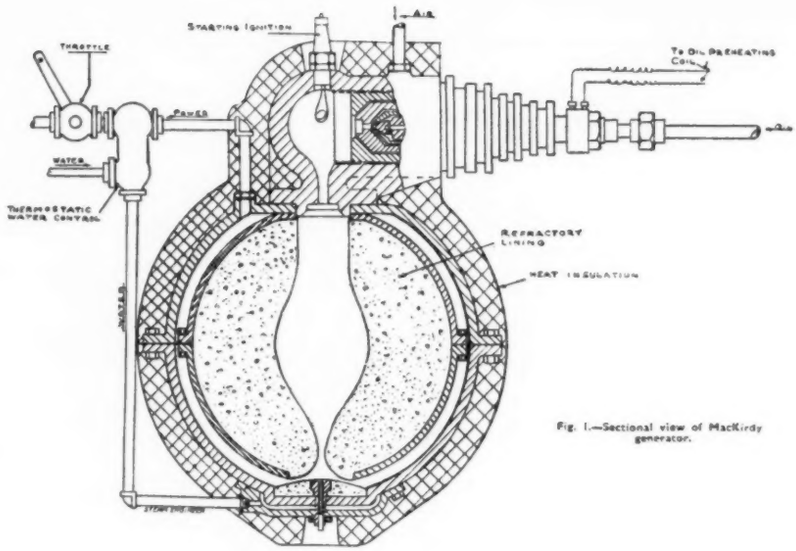


Fig. 1.—Sectional view of MacKirdy generator.

FIG. 4 SECTIONAL VIEW OF THE MACKIRDY GENERATOR

The double-acting pistons are mounted axially on a splined power shaft, this latter being the equivalent of an ordinary crankshaft. Caged in the cylinder wall are steel balls projecting half their diameter into specially formed grooves in the piston. By this arrangement each stroke of the piston rotates the power shaft 90 deg.

The secret of this invention appears to be in the venturi arrangement at the lower end of the combustion chamber. At this point the combustion gases under high temperature and pressure are caused to expand partially and meeting the water spray to generate steam. From this point the mixture passes through the annular space to the outlet at a workable temperature for engine or turbine. Combustion takes place under pressure, and the medium or gases are not called upon to perform work until after combustion is completed. (The *Steam Engineer*, vol. 5, no. 50, Nov., 1935, pp. 52–55, illustrated)

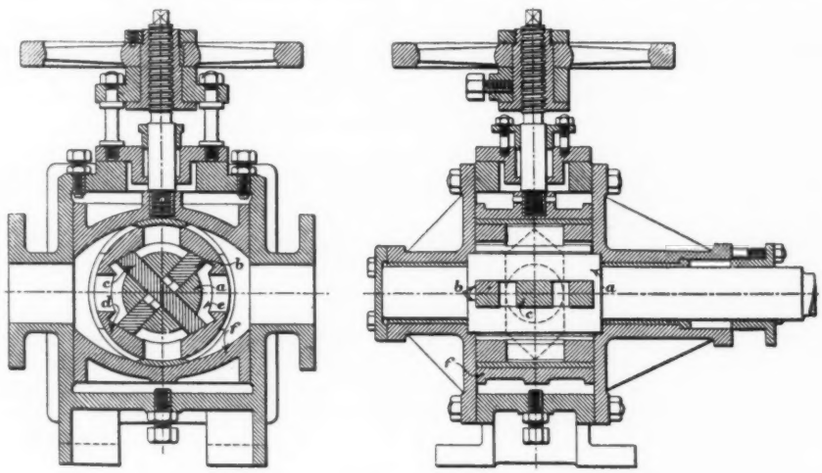
PUMPS

Cox Rotary Displacement Pump

THE Cox rotary displacement pump, manufactured in England, is either of the fixed-capacity type or of the variable-discharge, reversible type. Figs. 5 and 6 show this latter. In the drawings the parts are in neutral position, that is, set for no-load starting. The driving shaft *a* with its sliding vanes *b* and *c*, is then concentric with the ported rotor *d*, and the four sectors *e* are of equal volume, there being thus no displacing action. If, however, the casing *f*, in which the rotor revolves, is raised or lowered, it will be evident that the rotor is eccentrically displaced relative to the driving shaft, and the sectors change in volume as the rotor revolves, thus providing the necessary suction and delivery effects. It follows from this that the discharge can be infinitely varied in amount from zero to full capacity, and that raising the rotor center above that of the driving shaft gives a flow in one direction, while lowering it below that center results in a flow in the opposite direction, the direction of rotation of the driving shaft remaining unaltered during reversal, and its speed remaining constant during the changes in discharge.

The edges of the vanes are not tangential to the rotor, but are set at an angle and engage in the rotor in inclined recesses. These inclined edges of the vanes butt against the ends of the recesses to provide the drive for the rotor. The vanes are subject to only slight movement so long as the setting of the pump for a given discharge remains unaltered, but eccentric displacement of the rotor

alters the position of the vanes in the recesses, and for this reason extra width is given to the latter. It will be noticed that the edges of each pair of vanes are inclined in opposite directions. The pump can thus be run in either direction of rotation to suit that of the driving unit, that is, different patterns for clockwise or counterclockwise rotation are not needed, and the flow through the pump can be in either direction according to the upward or downward displacement of the rotor.



FIGS. 5 AND 6 THE COX ROTARY DISPLACEMENT PUMP

One of the advantages claimed for this pump is the economy of space, particularly noticeable in the nonreversing type. To give some idea of dimensions a "general" pump with suction and delivery branches of $2^1/_2$-in. bore is $9^3/_4$ in. high and 12 in. wide over the flanges. It will pump 2650 gal of Diesel fuel oil at a delivery pressure of 40 lb per sq in. when running at 530 rpm.

The variable-delivery pump is particularly suitable for handling a variety of liquids, as its capacity can be regulated to suit the viscosity. Thus one pump may be made to serve various purposes. Similarly, should the viscosity of the particular liquid handled vary, as with oil in cold weather, the capacity can be altered without fear of overloading. This type of pump is made in a number of sizes with a maximum delivery, at 100 rpm, ranging from 0.42 to 104 tons per hour with a total head of 50 ft. At a head of 200 ft, the range is from 0.37 ton to 96.2 tons per hour, the deliveries in all cases being with Diesel oil of a viscosity of 40 sec, Redwood No. 1, 100 F. The advantages of reversibility may be illustrated by the use of the pump on such a vessel as an oil tanker, in which the pump can draw from the store in loading and discharge at destination, the functions of the suction and delivery pipes being transposed and no change-over valves or bypass pipes being required. The pump is normally constructed for working pressures up to 500 lb per sq in., but is said to have been made for exceptional duties for a working pressure of 2000 lb per sq in. (*Engineering*, vol. 140, no. 3643, Nov. 8, 1935, pp. 498–499, 4 figs.)

RAILROAD ENGINEERING

Automatic Gear-Changing Locomotive

EIGHT new Planet locomotives constructed in England are all fitted with three-speed gear boxes which are fully automatic in operation, the control levers consisting of throttle, clutch, reversing lever, and brake. The gear change takes place at the correct revolutions for the load with the complete absence of jar. The engines are six-cylinder Blackstones, developing 55 hp at 1000 rpm.

The transmission system, built by F. C. Hibberd & Co., Ltd., consists of two devices, Freeborn friction clutch, and Freeborn automatic gear-changing mechanism. The friction clutch is shown in Fig. 7. It consists of a series of ring members mounted on the driving shaft. Pressure is maintained to keep these plates together. Carried on the driven member are five sets of disks mounted on spindles, which are fitted on a carrier in the same manner as the planet spindles of an ordinary epicyclic gear. The disks are interleaved between the ring members in a manner similar to the plates of a multidisk clutch, but the plates have less than half their surface in contact with the rings.

The whole clutch may be likened to an epicyclic train without a sun wheel and with frictional engagement of the members instead of tooth meshing. As long as a fixed pressure is maintained on the driving rings the clutch functions automatically under control of the speed of the driving member and of the torque required by the driven member. Thus, at low engine revolutions, the driving member rotates with its rings. The disks, under the influence of the friction applied to their surfaces in contact with the rings, rotate on their own centers, and the driven member does not move. This rotation results from the fact that only part of the surface of the disks—less than half—is in contact with the moving rings. This causes friction between the plates and the rings, which tends to stop the rotation of the disks. The resultant of the forces due to friction is equal to the friction between two crescents rotating at different angular velocities, the center of which is the center of gravity of the two crescents.

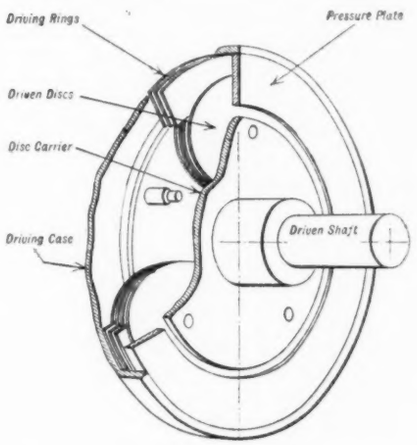


FIG. 7 DIAGRAM OF FRICTION CLUTCH

Friction is proportional to the area in contact which is constant, to the coefficient of friction which is constant, and to the relative velocities of the areas in contact which vary owing to the fact that velocity of the driving rings is proportional to the engine speed; while the velocity of the driven disks is proportional to the engine speed multiplied by the ratio of the mean diameters of the driving rings and the driven disks.

The friction therefore provides a braking force on the rotation of the disks increasing in value per revolution of the engine as the engine revolutions per minute increase. Eventually, the point is reached where the power required to rotate the disks is equal to the power required to move the disk carrier and with it the driven shaft. The drive then "takes up," the disk carrier rotates,

and, with any further increase in engine revolution, it follows the driving member. The power taken to drive it is balanced by the power required to rotate the disks against friction.

As the disk carrier rotates, so does the speed of rotation of the disks drop and friction decrease. Eventually, the engine revolutions are attained where the friction required to rotate the disks is greater than the power required to rotate the driven shaft at engine speed. The drive then becomes solid with no friction. This point naturally occurs at the same revolutions of the engine as the "take up" of the normal clutch. Below these revolutions perfectly graduated clutch slip has been provided automatically. Owing to the low speed and the short period in which the surfaces are in contact, the heat produced is not great, and as the surfaces not in contact at any instant are immersed in oil, rapid cooling occurs, the surfaces in contact being changed with great rapidity. This heat dispersal is sufficiently good to allow the clutch to be used with no means of removing the pressure applied to the driving rings, which is the function of the clutch lever provided.

The transmission provides two trains of reduction gears, in appearance similar to epicyclic trains. Their action, however, is that of a simple reduction gear, the planet wheels being actually layshaft wheels. Four of them are provided on a layshaft carrier so that when the reduction is locked the layshafts can rotate with the driven wheels as one unit giving "solid" direct drive. When in use the reduction gear operates without rotation of the planets. The method of locking each reduction is shown in Fig. 8. A multiple clutch is provided having its driving disks carried on a casing connected to the driven wheel. The driven disks are carried on the layshaft carrier of the reduction train. Pressure is applied to the rings by rockers which are operated by the mechanism shown in the plan view of Fig. 8. Here the centrifugal weights each carry on their lower edge a tooth or key which engages the driven unit. The carrier with the weights on it is keyed to the driven sun wheel of the reduction gear and itself forms the casing of the clutch. When the drive commences to rotate, the centrifugal weights are restrained from moving outward by the keys, which, as they are transmitting the torque, will not slide in their slots.

As the vehicle speed increases the torque is reduced and centrifugal force increases until it becomes greater than the friction on the teeth due to torque. The weights then fly outward throwing the clutch mechanism into engagement by means of the rockers. The clutch locks the layshaft carrier to the driven sun wheel, causing the reduction train to

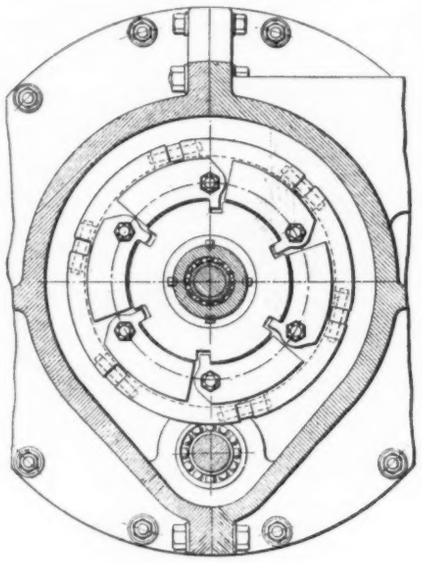


FIG. 8 CENTRIFUGAL CONTROL DEVICE

be locked solid. Thus, the higher gear is engaged until the locomotive speed is reduced to below a certain limit, when, the centrifugal force being reduced, the weights allow the clutch to release the driven wheel from the layshaft carrier again.

The torque acting on the key of the centrifugal weights provides the regulation of the gear changing to suit conditions. Thus, with light loads pressure on the keys is small and changing up or down occurs at low engine revolutions, but with bigger loads, or when rapid acceleration provides a large torque, the change is delayed to obtain the fullest use of engine power. In emergencies use can be made of this fact to cause the engine to change its own gear down before, for example, a hill is reached. The vehicle is slowed down until the change is desired, when the throttle is opened and the torque consequently increased momentarily. The change then takes place. (*The Engineer*, vol. 160, no. 4166, Nov. 15, 1935, pp. 510–511, 5 figs.)

SPECIAL PROCESSES

Electrodeposition of Bronze

THIS paper describes the results of an investigation of the use of the complex cyanide-stannate bath for the electrodeposition of bronze using bronze anodes. Preliminary experiments were made to determine the influence of the ratio of tin to copper in the solution on the composition of the bronze deposits.

It has been found that either thin or thick ($^1/_{32}$ in. and upward) deposits containing about 10 to 12 per cent of tin could readily be produced.

The corrosion resistance of mild steel sheets coated with bronze by the method described has been examined by means of the hot-water porosity test. This test reveals as rust spots the number and position of pores in the coating, each pore representing a point at which the basis metal is exposed, and which is thus a potential corrosion center.

After plating, the specimens were subjected to the hot-water porosity test. On withdrawal, the bronze was covered with a uniform dark oxide film on which the rust spots were just visible. This film was removed by washing the specimens in dilute sodium-cyanide solution, when the rust spots could be seen and counted more easily. Alternatively the specimens were plated with a flash of nickel, about 0.000005 in. thick, before testing. This procedure did not diminish the number of pores, and rendered the rust spots very distinct.

The results given in a table and curves in the original article show that the bronze deposits of more than 0.0003 in. in thickness are completely nonporous. (S. Baier and D. J. Macnaughtan, paper read before the Electrodepositors' Technical Society, London, October 30, 1935, abstracted through Electrometallurgy supplement to *The Metal Industry*, vol. 47, no. 22, Nov. 29, 1935, pp. 543–546, first installment, 6 figs.)

STEAM ENGINEERING

Streamlining Boiler Baffles

IT IS claimed that various advantages in the operation of vertical bent-tube boilers have been achieved by applying to these boilers the cross-baffle methods used with horizontal water-tube boilers. Also the gas passages have been tapered so that the passes are reduced in area to conform to the reduction of the volume of the gases as they cool in passing over the heating surfaces. It is claimed that by this method the velocity and hence the heat transfer is maintained constant, and draft loss otherwise caused by passing through a succession of narrow openings is avoided.

It has also been found advantageous to locate the front longitudinal baffle on the third row of tubes in the first bank when superheater construction permits. This is as far back as the radiant heat is effective and it has been demonstrated

that the gases do not penetrate to the rear of the first bank but rise vertically from the furnace to the opening of the first pass. As a result, practically all the work in the first bank is done by the first three rows of tubes as shown by the scale accumulation. Better results are therefore obtained by placing all but the first three rows of tubes back of the baffle and locating the lower cross baffle so as to flood these tubes with second-pass gases as the gases make their turn into the third pass. There was, at first, considerable apprehension as to the effect of

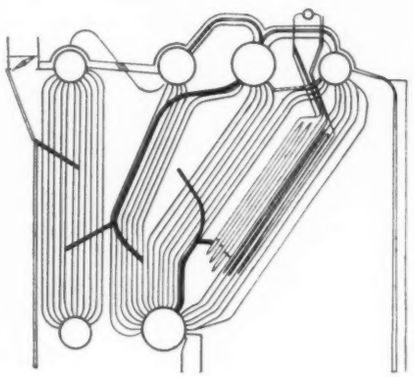


FIG. 9 BENT-TUBE TWO-DRUM INTEGRAL ECONOMIZER WITH CROSS BAFFLING

cross flow on the circulation of the water in the boiler but these fears proved to be unfounded.

A material aid in streamlining the baffles and reducing draft loss was obtained by devising methods of building curved surfaces to join the longitudinal and cross baffles. This seemingly impossible job was finally accomplished and the improvement was both immediate and considerable. The long sweeping curves eliminated eddy currents and promoted the smooth, rapid flow of the gas over the heating surfaces. Incidentally, dead gas pockets where soot, fly ash, and cinders accumulate, were eliminated and this heating surface made effective. The work of the soot blowers was also made much easier.

A design, shown in the article, which has been made more attractive by cross baffles, includes a bottom outlet through the rear wall, just above the mud drum. The gases are carried clear across all three banks of tubes and, after being returned through the second pass, flow under a short lower cross baffle extending outward from the rear wall at a point just above the outlet. This provides a convenient method of getting the gases into an air preheater or into a separate economizer if used. The gases then rise through the preheater or economizer and pass out through the stack, eliminating one vertical pass and preventing draft loss.

Certain effects on the economizer operation are noted. Fig. 9 shows a design in which the bent-tube two-drum integral economizer is supplied with cross baffling. This type of economizer is being more frequently used and cross baffling has been successfully applied to this construction. One advantage is the elimination of tube trouble sometimes experienced where hot gases pass over one side and cooler gases over the other, producing unequal expansion of the two tube banks. In the economizer here referred to one vertical movement of the gas can be eliminated, with reduction in load on the induced-draft fan. (Kingsley L. Martin, president, Engineer Co., in *Power Plant Engineering*, vol. 39, no. 12, Dec., 1935, pp. 692–694, 7 figs.)

VARIA

Present Status of British Machine-Tool Industry

IN MANY respects 1935 has been a notable year in the history of the British machine-tool industry. Following upon the largest and most successful exhibition of machine-shop equipment ever held in that country, there has been an almost unprecedented demand for machine tools of all types, which has been further stimulated by the continued improvement in trade and industry. There has been an expansion in machine-tool exports as compared with the previous year, and there is reason to suppose that the 1929 total will be equaled or excelled. The activity of the machine-tool industry, however, has been due mainly to the requirements of the home market, and there is ample evidence to show that the long delayed reorganization and re-equipment of the metal-working industries is now being carried out as rapidly as possible.

At the present time, indeed, the limiting factor is the ability of the machine-tool industry to produce. Every effort is being made to bring supply into line with demand, and those firms which, at the present time, are being inconvenienced and hampered owing to the lengthening of delivery dates, would do well to remember the difficult times through which the machine-tool industry has passed. A more rational policy of the plant replacement during recent years would have prevented the present congestion and permitted the engineering industries to take full advantage of the trade revival. It might be supposed that under the prevailing conditions machine-tool designers would have been content to rest upon their laurels. That this has not been the case is clearly shown by the review of new and improved designs. For the most part, attention has been directed to consolidating the advances of recent years by simplification of control and the incorporation of various refinements, in order that idle machine time may be brought into step with the reduced cutting times now possible. (*Machinery*, London, vol. 47, no. 1209, Dec. 12, 1935, editorial on p. 311)

WELDING

Gas Absorption in Steel Welding

THE conditions of the material welded, the process of welding, the use of additions to the metal, and the kind of electrode used all affect the absorption of the oxygen and the nitrogen.

Oxygen dissolves only slightly in unalloyed steel. At temperatures up to 900 C the quantity dissolved does not exceed 0.05 per cent; this rises to 0.1 per cent at temperatures up to 1400 C.

TABLE 1 ABSORPTION OF OXYGEN AS A FUNCTION OF THE CONTENT OF MANGANESE AND SILICON

Mn or Si, per cent	MnO_2 per cent	SiO_2, per cent
0.1	0.12	0.0086
0.2	0.06	0.0060
0.3	0.03	0.0050
0.5	0.025	0.0038
0.8	0.015	0.0030
1.0	0.012	0.0027
1.5	0.008	0.0022
2.0	0.006	0.0019

As shown in Table 1, the absorption of oxygen decreases with the increase of the content of manganese or silicon. The absorption of oxygen in gas welding is slight because of the reducing character of the acetylene flame, but if arc welding has been used as much as 0.3 per cent of oxygen may be present. An oxygen content not exceeding 0.2 per cent reduces the tensile strength from 42 to 32 kg per sq mm, and the elastic limit from 32 to 18 kg per sq mm, while elongation remains unaffected.

At room temperature nitrogen dissolves only slightly in steel, say 0.001 per cent, but 0.13 per cent is dissolved at as low a temperature as 600 C. The nitrogen appears chiefly as Fe_4N; its structure is braunite, nitromartensite, and nitroaustenite. (*Zeitschrift des Vereines deutscher Ingenieure*, vol. 80, no. 6, Feb. 8, 1936, p. 148.)

LETTERS AND COMMENT

Brief Articles of Current Interest, Discussion of Papers, A.S.M.E. Activities

Rounded-Approach Orifices

To the Editor:

In your December, 1935, issue it was noted by Smith and Steele[1] that the line connecting the points of their data at low Reynolds numbers has the equation $c = 0.077\ Re^{0.48}$. If we examine the equations for the steady flow of a viscous, incompressible fluid some information on this matter can be obtained.

The equations of Navier-Stokes[2] are

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = X - \frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{\mu}{\rho}\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) \quad \ldots[1]$$

with the corresponding equations in y and z.

Consider two flow fields having geometrically similar stream lines. If corresponding points in the two fields are defined by

x, y, z proportional to D, any dimension (such as radii or diameters of pipes),

then u, v, w are proportional to V, any velocity (such as maximum velocity in pipes).

It follows that differences in these quantities between pairs of corresponding points vary in the same manner; that is, dx, dy, dz, when taken proportional to D, cause the corresponding du, dv, dw to be proportional to V.

Therefore

$$\left.\begin{aligned} u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} &= KV^2/D \\ \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} &= KV/D^2 \end{aligned}\right\} \quad \ldots[2]$$

with the corresponding equations in y and z, where the K's are proportionality factors and are, in general, different functions of xyz.[3] For steady flow and no unbalanced body forces, Equations [1] become, after substitution of [2]

$$\frac{\partial p}{\partial x} = K\frac{\mu V}{D^2} + K\frac{\rho V^2}{D} = K\frac{\mu V}{D^2}\left(1 + K\frac{VD\rho}{\mu}\right) = K\frac{\mu V}{D^2}\left(1 + K\,Re\right) \quad \ldots[3]$$

with the corresponding equations in y and z.

The pressure drop between any pair of corresponding points in the two fields can be obtained from Equations [3] by an integration involving only the K's and gives, with the relation between dx, dy, dz, and du, dv, dw already noted

$$\Delta p = K\frac{\mu V}{D}\left(1 + K\,Re\right) \quad \ldots[4]$$

To apply this to flow coefficients note that the actual flow $W = K\rho VD^2$ and the theoretical flow $W_0 = KD^2(\rho\Delta p)^{1/2}$. Therefore

$$c = \frac{W}{W_0} = K\frac{\rho^{1/2}V}{\left[\frac{\mu V}{D}\,(1 + K\,Re)\right]^{1/2}} = \left(\frac{K\,Re}{1 + K\,Re}\right)^{1/2} = \left(\frac{K_1}{1 + K_2\lambda}\right)^{1/2} \quad \ldots[5]$$

where $\lambda = 1/Re$, and K_1 and K_2 are to be determined from the experimental results.

Equation [4] applied to pipe friction factors gives

$$f = K_3 + \frac{K_4}{Re} \quad \ldots[6]$$

Equations [5] and [6] are to be regarded as criteria of geometric similarity of flow fields. The degree of exactness with which these equations can be made to fit the experimental data shows the degree of similarity of the flow fields concerned.

For the case of known similarity, that of laminar flow in pipes, the analytical derivation of the friction factor gives $f = 16/Re$ or $K_3 = 0$, $K_4 = 16$ in Equation [6]. As is also known, turbulent flows in pipes are not geometrically similar at different Reynolds numbers and no K_3 and K_4 exist which will satisfy the experimental results. Equation [6] thus checks with previous knowledge of the similarity of flow in pipes and gives us some confidence in the use of other equations derived from Equation [4].

Turn now to flow coefficients and Equation [5]. Note that as $Re \to \infty$, $\lambda \to 0$, and, therefore, $c_\infty = K_1^{\frac{1}{2}}$. Also note that as $Re \to 0$, c becomes proportional to $Re^{\frac{1}{2}}$. As it is reasonable to expect that all laminar flows through any given hole will be geometrically similar, c should be proportional to $Re^{\frac{1}{2}}$ for low Re for any metering device. The data of Smith and Steele show c proportional to $Re^{0.48}$ for Re between 10^0 and 10^1. Coefficient curves for a venturi and for a sharp-edged-orifice taken from Fig. 1 of "Quantity-Rate Fluid Meters"[4] are typical curves for these devices. (See Fig. 1 of this discussion.) They both show that the coefficient becomes constant for $Re \to \infty$ and in both cases c is proportional to $Re^{0.51}$ for $Re < 10$.

To fit Equation [5] to the data of Smith and Steele set $c_\infty = 1$, or $K_1 = 1$ and use point $Re = 10^0$, $c = 0.075$ to determine K_2. Thus

$$c = \left(\frac{1}{1 + 177\lambda}\right)^{1/2} \quad \ldots[7]$$

This is drawn in Fig. 1 and shows the extent to which the actual flows through a nozzle at different Reynolds' numbers approach geometric similarity.

As would be expected, the venturi data if tested by Equation [5], show flow similarity about the same as the nozzle of Smith and Steele. For an orifice, however, definite lack of similarity is shown. The equation

$$c = \left(\frac{0.36}{1 - 1450\lambda}\right)^{1/2} \quad \ldots[8]$$

[1] "Rounded-Approach Orifices," by J. F. Downie Smith and Sydney Steele, Mechanical Engineering, December, 1935, pp. 760 and 780.

[2] "Fundamentals of Hydro- and Aeromechanics," by Prandtl-Tietjens, translation by L. Rosenhead, McGraw-Hill Book Co., New York, 1934, p. 259.

[3] To avoid many subscripts on the K's, none has been added in this discussion. For example, in Equation [4] the two K's are not alike.

[4] "Quantity-Rate Fluid Meters," by Ed S. Smith, Jr., Trans. A.S.M.E., vol. 52, 1930, paper HYD-52-7*b*, pp. 89–109.

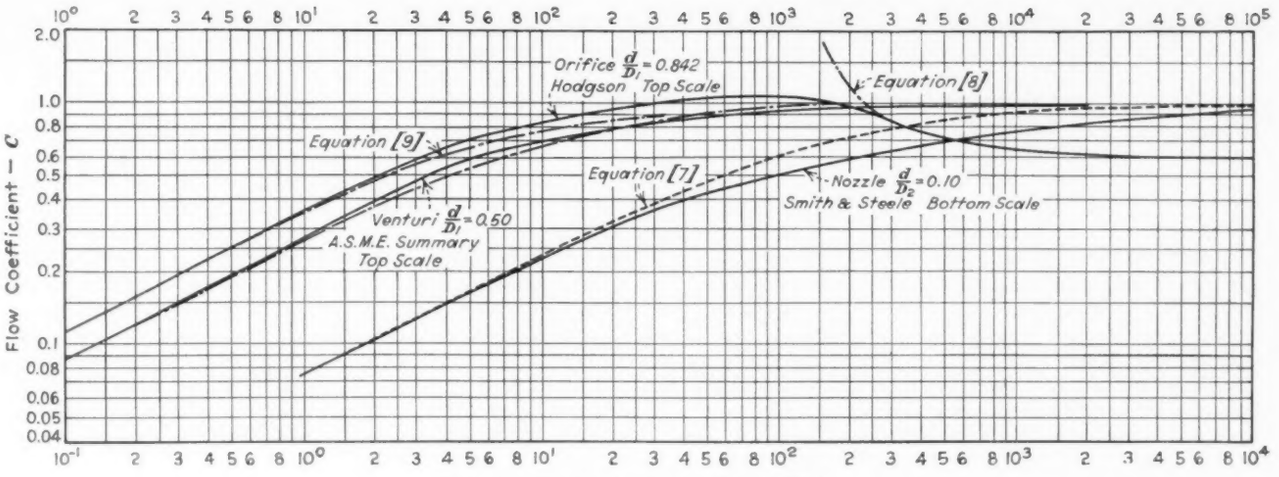


FIG. 1 REYNOLDS' NUMBER $Re = VD/\nu$

(In throat for nozzle curve; in approach pipe for orifice and venturi curves.)

fits the curve above $Re = 2.5 \times 10^3$ and

$$c = \left(\frac{1}{1 + 72\lambda}\right)^{1/2} \quad \ldots\ldots\ldots [9]$$

fits for Re below 10^2.

Physically, this decided lack of similarity with an intermediate transition region is not surprising, as the jet from an orifice, which must be considered when one pressure tap is behind the orifice, is in no way similar to the laminar flow which exists at very low Reynolds numbers.

NOMENCLATURE

Besides the symbols given in Table 2 of the Smith and Steele paper, the following have been used in this discussion:

Symbol	Unit	Significance
c_∞	....	Coefficient approached as $Re \rightarrow \infty$
D	ft	Any dimension
f	....	Friction factor
K	....	Dimensionless proportionality factor
V	ft per sec	Any velocity
u, v, w	ft per sec	Velocity components
x, y, z	ft	Rectangular coordinate axis
λ	....	$1/Re$
μ	lb sec/ft^2	Absolute viscosity
ν	ft^2/sec	μ/ρ
ρ	lb sec^2/ft^4	Mass density

HOWARD EMMONS.[5]

TO THE EDITOR:

The discussion by Mr. Howard Emmons is interesting, and gives a logical background for building a suitable equation for flow coefficients under specified conditions. It should be noted, however, that over a range of Reynolds' numbers from 100 to 1000, the difference between Emmons' equation and the experimental curve of Smith and Steele is never less than 20 per cent, and for a good part of this range the discrepancy is greater than 25 per cent. For this reason the authors recommend the continued use of the experimental curve.

J. F. DOWNIE SMITH.[6]
SYDNEY STEELE.[7]

Water-Cooled Underfeed Stoker

TO THE EDITOR:

The article on the "Design and Development of a Water-Cooled Underfeed Stoker," in your issue of December, 1935, recalls the beginning of active interest in water-cooling about 12 or 13 years ago, when Kreisinger and Bell were conducting experiments at the Oneida Street Station, Milwaukee, Wis., with floor-screen and rear-wall cooling, which development was later adopted in the Lakeside Station under construction at the time the tests were being conducted at the Oneida Street Station. In 1923, the fin-tube wall designed by T. E. Murray was installed at the Hell Gate Station, New York, N. Y.

At the time of these installations there were many predictions of failure by skeptics who could not recognize the dawn of a new era in furnace design. This development has since proved to be one of the greatest single advancements in furnace construction and has resulted in making possible almost complete control of furnace temperatures with any predicted coal.

Since water-cooling has accomplished so much in the furnace, it is perfectly logical to assume that much improvement can be brought about in the fuel bed of the stoker by intelligent experiment and development. In this respect considerable credit is due Messrs. Bennett and Herbeck, the authors, for the consistent work they have done and the results they have obtained.

From a careful observation of the operation of the stoker discussed in the paper, it is evident that this type of construction has come to stay. One has only to study the character of the fire and watch the flow meter and CO_2 recorder as compared to the standard-type stoker, to justify this prediction.

A. E. DURAM.[8]

TO THE EDITOR:

Messrs. Bennett and Herbeck's paper on the "Design and Development of a Water-Cooled Underfeed Stoker" published in the December, 1935, issue of MECHANICAL ENGINEERING is interesting in view of previously published A.S.M.E. paper,[9] "The Economics of Preheated Air for Stokers." From a study of this later paper it would appear that some form of water-cooling is desirable with multiple-retort underfeed stokers when using highly preheated air for combustion, or when the fuel has a low ash-fusing temperature, or even with fuel having a high ash-fusing temperature

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[7] Chemical Engineer, E. I. du Pont de Nemours & Co., Niagara Falls, N. Y.

[8] Sales Engineer, Springfield Boiler Company, Springfield, Ill. Mem. A.S.M.E.

[9] "The Economics of Preheated Air for Stokers," by R. E. Dillon and M. D. Engle, Trans. A.S.M.E., vol. 56, 1934, paper FSP-56-17, pp. 879–884.

but low ash content. A great many coals having a low ash-fusing temperature also have a fairly high volatile content, with the result that they ignite freely and burn with rather intense heat near the surface of the fuel bed, resulting in the formation of clinkers. It would appear that the use of some form of water-cooling for the tuyère blocks would aid considerably in the burning of these fuels and preventing the formation of clinkers at the surface of the fuel bed which eventually results in the burning or blocking of the stoker tuyères.

The water-cooling of tuyères in underfeed stokers was proposed more than 40 years ago. One early construction included a water tube formed in a loop extending around the edge of the retort in a Jones single-retort stoker. The tube was cast into the tuyère structure. This construction was apparently not received enthusiastically, as but little evidence of its continued use can be found. So far as the writer is aware, the first practical application of water-cooling of tuyères in a multiple-retort stoker was made in 1929, when difficulty was encountered with tuyère-block maintenance on a stoker at the plant of the Stamford Gas and Electric Company, Stamford, Conn. This stoker was operated with highly preheated air. In order to increase the life of the tuyère structure, eight water tubes of 1 in. diameter were mounted between each pair of retorts, and tuyère blocks were secured to the water tubes to form the actual fuel contacting surfaces.

This construction greatly increased the life of the heat-exposed parts, but certain combustion difficulties were still encountered. Since the water tubes were covered by the tuyère blocks, the cooling effect of the tubes was greatly reduced. The highly preheated air resulted in extremely high temperatures in the fuel bed, resulting in formation of clinkers and stoppage of tuyère openings. In order to increase the cooling effect and protect the tuyère openings from plugging, it was proposed to utilize exposed water tubes with tuyère blocks beneath. Before this could be tried out, however, it was decided to change over the plant to pulverized coal and thus avoid all the difficulties which are encountered when highly preheated air is used with underfeed stokers.

It is the writer's opinion that if water tubes are to be used in multiple-retort stokers, the tubes should be exposed to contact with the fuel bed to obtain the maximum cooling effect, and that tuyère blocks should be located beneath the water tubes, as has been described by the authors. With this construction, the water tubes are used to support the fuel bed between the retorts, where the temperature is at its maximum, and to reduce the temperature of the fuel bed and thus decrease the formation of clinkers. The tuyère blocks are to a large extent protected from contact with the hot fuel, the life of the tuyère blocks is prolonged indefinitely, and plugging of the tuyère openings is avoided. Close contact between the tuyère blocks and the tubes is not essential, as it is when the blocks are mounted on top of the tubes.

Undoubtedly it would be necessary to be careful of the feedwater treatment used on an installation with the water-cooled stoker. There would be sufficient heat absorbed to cause the deposition of scale-forming material and since the water-cooling tubes, of necessity, must be comparatively small, it will not be easy to clean them. The location of the tubes is such that if steam were formed in them it would rise to the surface to which heat is applied, so that it is quite important that the treatment of the boiler feedwater be such as to remove all scale-forming material.

JAMES W. ARMOUR.[10]

TO THE EDITOR:

The introduction of water-cooling of the grates is a logical development which should enlarge the field of underfeed stokers and should reduce the labor of operation. One would imagine that the main function of the cooling is to chill the slag so that it will not adhere to the iron and it would be interesting to examine the resulting clinkers. In an ideal underfeed stoker the clinker should not come in contact with the metal until the bed reaches the overfeed grates as it should be kept away by the coal fed in from below, but if the slag is very fluid some of it may run through the coal; also the underlying coal may be burned out during changing of rates of operation or because of irregular burning.

It seems possible that in the construction used the tubes above the tuyères will interfere with the feeding of the coal onto the tuyères, with the result that the fuel over the tubes will be thin and the excess air higher than desired. Such action would probably be more in evidence with coals having higher caking characteristics than found in the Western coals.

P. NICHOLLS.[11]

[10] Vice-President and Engineering Manager, Riley Stoker Corporation, Worcester, Mass. Mem. A.S.M.E.

[11] Supervising Engineer, Fuels Section, Pittsburgh Experiment Station, U. S. Bureau of Mines, Pittsburgh, Pa. Mem. A.S.M.E.

TO THE EDITOR:

Mr. James W. Armour's description of his experiences with the application of water cooling to an underfeed stoker would lead us to conclude that there must have been some serious defects in the design of the original machine because this stoker, even with the advantage of water cooling, was not able to do what other makes of underfeed stokers have accomplished without the protection afforded by water cooling. Our belief that the stoker mentioned by Mr. Armour was of unsound design is confirmed by the fact that the equipment was replaced at considerable expense without making an attempt to apply tubes above the air-admitting surfaces, although Mr. Armour states that this is the best method. It is certain that this simple step would have been taken unless the basic design of the stoker were wrong. It is unfortunate that water cooling employed in 1929 was not applied to the type of underfeed stoker that would have been successful. Failure to do so has deprived the combustion field of this advance for a number of years. Since that time water cooling has been applied to underfeed stokers both above and below the tuyères with equal success.

We cannot understand the reason for Mr. Armour's comments regarding the necessity for using good water with a water-cooled stoker. The water tubes in the stoker differ in no respect from any other waterwall tubes, they are connected into the boiler circulation in the same way, and cleaned in the same manner.

With reference to P. Nicholl's question regarding the feeding of the fuel over the tuyères on a water-cooled stoker, we have been unable to detect any difference in the appearance of the fuel bed with and without water cooling, except for the apparent greater porousness and looseness of the water-cooled stoker fuel bed. The mechanical obstruction offered by the tubes is so slight and the thickness of the fuel above the tuyères is so great that it seems doubtful if this could have any effect. Orsat readings taken at the boiler outlet on numerous water-cooled stoker furnaces have indicated that as high as 17 per cent CO_2 has been maintained. Experience with Pittsburgh coals burned on a water-cooled stoker has shown equally great improvements.

J. S. BENNETT.[12]
C. J. HERBECK.[13]

[12] Mechanical Engineer, American Engineering Company, Philadelphia, Pa. Mem. A.S.M.E.

[13] Chief Engineer, Cedar Rapids Station, Iowa Electric Light & Power Co.

Electrical Precipitation of Cinders

TO THE EDITOR:

The installation of electric precipitators[14] in series with static cinder trap catchers for stoker-fired boilers at the central heating plant for public buildings in Washington, D. C., represents a rather unique and interesting combination for the elimination of cinders and dust.

The overall performance of the electrostatic unit used in series with the baffle trap unit strikingly illustrates the fact that the selective characteristic of the cinder trap in removing the coarse high-carbon particles properly supplements the characteristics of the electrostatic precipitator which effectively removes the light and fine particles of material. Such a series combination for cinder removal might appear rather elaborate to power-plant engineers for the average stoker-fired plant, not only in cost but in space allotment needed to make a good engineering layout of the equipment required for efficient power production.

Unquestionably the dust nuisance must be met, particularly in large cities and residential communities. However, stoker cinder has not generally been regarded as a difficult material to recover from flue gases because of the size and weight of the material.

The New York Edison Company has been using for many years at the Waterside, Hell Gate, and Sherman Creek stations a simple water-baffle cinder catcher which has proved highly effective in removing cinders. This unit consists of a tank in which the flue gases are caused to sweep at high velocity over water maintained at a constant level. The cinders impinge against the water surface and are removed from the gas. Exhaustive tests of these cinder catchers have indicated efficiencies of close to 80 per cent.

While the use of the impingement principle in this form has proved effective for stoker cinders, this same device applied to pulverized-coal fly ash suffers a sharp impairment of efficiency. Since 1924 the New York Edison Company has tested a great variety of fly-ash eliminators. The most promising indications were obtained in 1924 by using a finely divided water spray for eliminating the dust. Since that time the problem of corrosion and excessive use of water has been worked out by successive development and test and has resulted in the design of what has been termed the "spray-zone fly-ash eliminator" in which a great reduction in the amount of water required has been accomplished. One of these eliminators has been in operation for about four years on boiler No. 83 at the Hell Gate station. This boiler is a large pulverized-coal-firing unit with a rated capacity of 400,000 lb of steam per hr. The spray-zone eliminator is (1) comparatively simple, (2) compact, (3) requires little operating attention, (4) has moderate draft loss, (5) uses river water at comparatively low pumping power, and (6) has a developed efficiency of 97 per cent. One of the attractive features of this eliminator is that the use of water removes a substantial percentage of the obnoxious sulphur fumes as well as a high percentage of the dust.

Fig. 1 shows a cross section of the spray-zone eliminator on boiler No. 83 at the Hell Gate station. It occupies a space 9 ft deep by 34 ft wide and 14 ft high, a space in which no other eliminator which might have been considered would fit. About 1.75 lb of water per lb of coal burned is required in the spray zone. This compares with 20 lb of water per lb of coal burned as reported for the Battersea spray development in England. The pumping charges for spray water are about 10 kw per hr. Fig. 2 indicates the test efficiencies of the eliminator. Table 1 gives some details of the fly-ash characteristics of this eliminator which indicate that the performance is not selective to the extreme fines, the coarse material, or the intermediate sizes.

A second boiler at the Hell Gate station is being equipped with the spray-zone eliminator. Based on past experience, the problem of corrosion is being met by lining the steel interior of the box with lead, using the homogeneous process for this purpose. Moisture is prevented from leaving the catcher by discharging the gases through a dehydrating section.

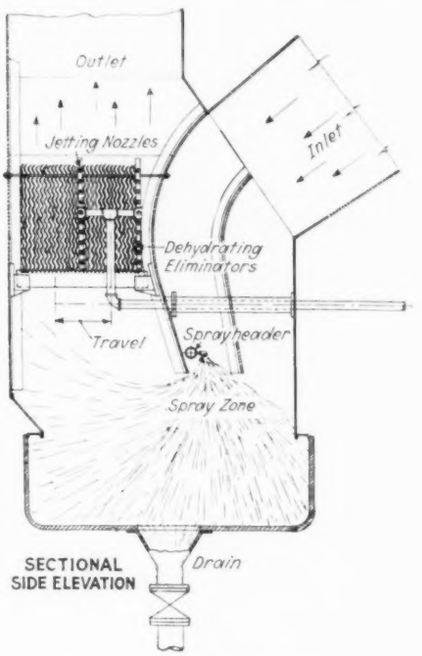

FIG. 1 HELL GATE SPRAY-ZONE FLY-ASH ELIMINATOR

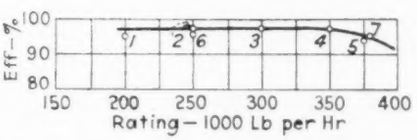

FIG. 2 EFFICIENCIES OF CINDER CATCHER ON BOILER NO. 83, HELL GATE STATION

In regard to space requirements the writer would like to ask Mr. Hedberg, approximately what volumetric space is occupied by the dust-reclaiming equipment, as laid out, for the Washington heating plant? Also what effect, if any, is produced on the sulphur fumes in the flue gas by the electrostatic charge?

About what ratio of weight does this

[14] "Electrical Precipitation for Stoker-Fired Boilers," by C. W. Hedberg, MECHANICAL ENGINEERING, vol. 58, January, 1936, pp. 25–29.

TABLE 1 DETAIL OF FLY-ASH CHARACTERISTICS OF THE SPRAY-ZONE FLY-ASH ELIMINATOR[a]

Steam rating, lb per hr	Fineness, per cent through mesh — Inlet cinder				Outlet cinder				Combustible, per cent		Eff, per cent
	60[b]	100[b]	200[b]	325[b]	60[b]	100[b]	200[b]	325[b]	Inlet	Outlet	
250000	97.0	89.0	81.8	68.0	99.0	97.5	96.5	73.0	34.9	30.8	96
300000	95.7	91.3	83.4	57.3		Insufficient material			14.7	..	97
350000	89.8	79.8	66.2	39.2		Insufficient material			26.4	27.7	97
375000	94.5	89.0	81.7	61.8	94.5	89.0	81.7	55.3	24.3	25.6	94
380000	92.0	86.0	76.1	68.5	91.5	84.0	74.5	65.2	15.4	20.4	95

[a] Screening of the fly-ash samples indicates that the eliminator is not sensitive to either the fine or the coarse-material. Samples from tests of eliminator serving no. 83 boiler at Hell Gate station.

[b] Mesh sizes.

electrostatic precipitator bear to one of equivalent gas-handling capacity with concrete plates?

What is the range of gas velocities through the precipitator?

Unquestionably the electrostatic precipitator under the conditions of this installation is doing a very fine job and Mr. Hedberg's paper represents a welcome addition to the general knowledge of dust elimination.

JOHN J. GROB.[15]

TO THE EDITOR:

Mr. Grob states: "The selective characteristic of the cinder trap in removing the coarse high-carbon particles properly supplements the characteristic of the electrostatic precipitator which effectively removes the light and fine particles of material."

It may be erroneously inferred from this that this precipitator does not effectively remove coarse material. If "coarse material" be defined as particles of a size that remain on a 200-mesh screen it is a fact that this precipitator actually removes a considerably greater weight of coarse material than does the cinder trap which precedes it. This, of course, is in addition to the material finer than 200 mesh which makes up about 65 per cent of the material as collected in the precipitator. It is also a fact that this type of precipitator is equally effective for both coarse and fine particles.

Mr. Grob asks specifically about space requirements, the weight of this precipitator relative to that of a concrete-plate precipitator of equal capacity, and also the range of gas velocities used. The precipitator described occupies a space which is approximately 30 ft by 12 ft. The overall height is 45 ft, which includes a hopper approximately 10 ft deep. Its weight is about 60 per cent of that of a concrete-plate precipitator of equivalent capacity. Based on the effective cross-section area of the ducts the average gas velocity at rating is 10 ft per sec.

With reference to Mr. Grob's other question regarding effects of electrostatic charges on sulphur fumes in the flue gases, no exact data are available. While we have found indications that some sulphur dioxide is converted through the action of the corona discharge into sulphur trioxide, which is then fixed by combining with basic constituents of the suspended solids and thus removed from the gases, the action is far from complete. There are also indications that some of the sulphur dioxide is adsorbed in the precipitated soot and that the amount is probably small. Under any conditions the total effect is probably unimportant from the standpoint of sulphur-compound removal.

C. W. HEDBERG.[16]

[15] Engineer of Tests, New York Edison Company, Inc. Mem. A.S.M.E.

[16] Chief, Technical and Development Department, Research Corporation, Bound Brook, N. J.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following are records of the interpretations of this Committee formulated at the meeting of January 17, 1936, and approved by the Council.

CASE NO. 815

(*Interpretation of Par. MA-4*)

Inquiry: Does the 95 per cent minimum requirement for the reduced-section tension-test specimen in Par. MA-4 apply only in case the failure under test takes place through the weld or through the line of fusion? If it fails outside the weld in the solid plate, must the tensile strength equal the minimum of the specified range of plate used?

Reply: It is the opinion of the Committee that in revising Par. U-68*e*, the requirement that the tension test of the joint specimen as specified is intended as a test of the welded joint and not of the plate, was inadvertently omitted in Pars. U-69 and MA-4.

CASE NO. 816 (ANNULLED)

CASE NO. 817

(In the hands of the Committee)

CASE NO. 818

(*Interpretation of Pars. P-301 and H-93*)

Inquiry: Will a valve of the plug-cock type with forced lubrication and fitted with a slow opening mechanism meet the intent of the requirements of Pars. P-301 and H-93?

Reply: It is the opinion of the Committee that the intent of the Code will be met if a valve of this type is fitted with a slow opening mechanism and with a device which will indicate at a distance whether it is closed or open, and the plug is held in place by a guard or gland.

Revisions and Addenda to Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the Rules and its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later in the proper place in the Code

The following proposed revisions have been approved for publication as proposed addenda to the Code. They are published below with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticism and approval from any one interested therein. It is to be noted that a proposed revision of the Code should not be considered final until formally adopted by the Council of the Society and issued as pink-colored addenda sheets. Added words are printed in SMALL CAPITALS; words to be deleted are enclosed in brackets [ ]. Communications should be addressed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

PAR. P-282. Insert the following after the second sentence:

"The lifting lever shall be such that it cannot lock or hold the valve disk in lifted position when the exterior lifting force is released."

PAR. P-301. Revise second sentence to read:

"When such outlets are over 2-in. pipe size, the valve or valves used on the connection shall be of the outside-screw-and-yoke rising-spindle type OR OF SUCH OTHER TYPE AS TO indicate AT A DISTANCE by the position of its spindle OR OTHER OPERATING MECHANISM whether it is closed or open, and the wheel may be carried either on the yoke or attached to the spindle. IF THE VALVE IS OF THE PLUG COCK TYPE IT MUST BE FITTED WITH A SLOW-OPENING MECHANISM (SEE PAR. P-311) AND AN INDICATING DEVICE, AND THE PLUG MUST BE HELD IN PLACE BY A GUARD OR GLAND."

PAR. P-314. Add the following sentence:

"When the boiler is under pressure feedwater shall not be introduced through the openings or connections used for the water column, the water-gage glass, or the gage cocks. In closed systems the water may be introduced through any opening when the boiler is not under pressure."

PAR. A-19. Revised:

A-19. *A* Fire-actuated fusible plugs, if used, shall be filled FROM THE WATER SIDE AND TO THE POINT OF LEAST DIAMETER OF THE HOLE IN THE CASING with tin OF THE FOLLOWING COMPOSITION, having a melting point between 400 and 500 F:

PURE TIN, MINIMUM, PER CENT	99.3
COPPER, MAXIMUM, PER CENT	0.5
LEAD, MAXIMUM, PER CENT	0.1
TOTAL IMPURITIES, PER CENT	0.7

B THE FILLING SHALL BE CAREFULLY ALLOYED WITH THE CASING.

C THE FUSIBLE PLUGS [and] shall be renewed AT LEAST once each year.

D When the boilers are [to be] operated at working pressures in excess of 250 [225] lb per sq in., the use of fusible plugs is not advisable.

PAR. A-20. Revised:

A-20. *A* WATER-SIDE PLUGS ARE FUSIBLE PLUGS WHICH ARE INSERTED FROM THE WATER SIDE OF THE PLATE, FLUES OR TUBES TO WHICH THEY ARE ATTACHED. FIRE-SIDE PLUGS ARE FUSIBLE PLUGS INSERTED FROM THE FIRE SIDE OF THE PLATE, FLUE, OR TUBE TO WHICH THEY ARE ATTACHED.

B THE CASING OF FUSIBLE PLUGS SHALL BE MADE OF BRONZE OF THE FOLLOWING COMPOSITION:

COPPER, MINIMUM, PER CENT	86.0
TIN AND ZINC COMBINED,[1] MINIMUM, PER CENT	10.0
LEAD, MAXIMUM, PER CENT	0.3

[1] ZINC AND LEAD MAY BE REDUCED OR ELIMINATED IF REPLACED BY COPPER AND TIN.

C THE DESIGN OF CASINGS SHALL BE IN ACCORDANCE WITH FIG. A-10.

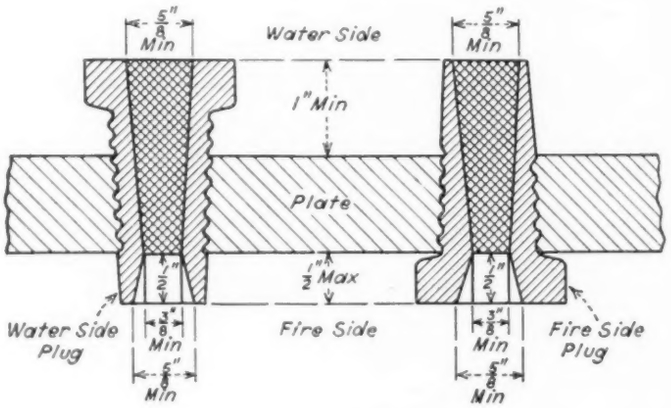

FIG. A-10 INSTALLATION OF FUSIBLE PLUGS

D THE BORE OF THE CASING SHALL BE TAPERED CONTINUOUSLY AND EVENLY FROM THE WATER END OF THE PLUG TO A DIAMETER OF NOT LESS THAN 3/8 IN. AT A POINT 1/2 IN. FROM THE FIRE END. THE DIAMETER OF THE BORE AT EITHER END OF THE PLUG SHALL NOT BE LESS THAN 5/8 IN.

E A FUSIBLE PLUG SHALL BE OF SUCH LENGTH THAT WHEN INSTALLED, IT SHALL PROJECT AT LEAST 1 IN. ON THE WATER SIDE OF THE PLATE, TUBE OR FLUE AND AS LITTLE AS POSSIBLE BUT NOT MORE THAN 1/2 IN. ON THE FIRE SIDE. If a fire-actuated fusible plug is inserted in a tube, the tube-wall shall be not less than 0.22 in. in thickness or sufficient to give four full threads.

[The least diameter of fusible metal in a fire-actuated plug shall be not less than 1/2 in., except for maximum allowable working-pressures of over 175 lb per sq in., or when it is necessary to place a fire-actuated fusible plug in a tube, in which case the least diameter of fusible metal shall be not less than 3/8 in. (See Fig. A-10).]

TABLE A-10. Add the following:

Pressures given in American Standards for 750 F					
100	300	400	600	900	1500
Maximum pressures at which boilers can be operated when using the above standard flanged fittings for feed and blow-off service under Pars. P-299 and P-310.					
...	318	416	605	878	1395

PARS. H-38 AND H-91. Add the following sentence:

"Feedwater shall not be introduced through the openings or connections used for the water column, the water-gage glass, or the gage cocks."

PAR. H-93. Revise fifth section to read:

"When stop valves over 2 in. in size are used, they shall be of the outside-screw-and-yoke RISING-SPINDLE TYPE OR OF SUCH TYPE AS TO INDICATE AT A DISTANCE BY THE POSITION OF ITS SPINDLE OR OTHER OPERATING MECHANISM WHETHER IT IS CLOSED OR OPEN, AND THE WHEEL MAY BE CARRIED EITHER ON THE YOKE OR ATTACHED TO THE SPINDLE. IF THE VALVE IS OF THE PLUG COCK TYPE IT MUST BE FITTED WITH A SLOW-OPENING MECHANISM AND AN INDICATING DEVICE, AND THE PLUG MUST BE HELD IN PLACE BY A GUARD OR GLAND."

PAR. M-13. Add the following sentence:

"When the boiler is under pressure feedwater shall not be introduced through the openings or connections used for the water column, the water-gage glass, or the gage cocks. In closed systems the water may be introduced through any opening when the boiler is not under pressure."

PAR. MA-3. Revise the first two sections to read:

Test Specimens. [Two full-section tension-test specimens] Two reduced-section tension-test specimens, two nick-break-test specimens, and two bend-test specimens shall be required from each test plate.

[*Full-Section Tension-Test Specimen.* The shape and dimensions of the tension-test specimen shall be as shown in Fig. MA-2, with the weld at the center. Data shall be recorded on the ultimate strength and computed from the area of the base-metal section (pounds per square inch).]

PAR. MA-4. Revise second section to read:

Tension Tests. [Each full-section tension specimen should fail in the plate if the weld reinforcement is retained, but if failure occurs in the weld metal or along the line of fusion between the weld metal and the plate, then the tensile strength shall not be less than the minimum of the specified tensile range of the plate used.] For the reduced-section tension-test specimens the tensile strength shall not be less than 95 per cent of the minimum of the specified tensile range of the plate used. (THE TENSION TEST OF THE JOINT SPECIMEN AS SPECIFIED HEREIN IS INTENDED AS A TEST OF THE WELDED JOINT AND NOT OF THE PLATE.)

FIG. MA-1. Omit reference to full-section tension-test specimen.

FIG. MA-2. Omit.

PAR. U-69*c*. Omit second section which reads:

[*Full-Section Tension-Test Specimen.* The shape and dimensions of the tension test specimen shall be as shown in Fig. U-14, with the weld at the center. Data shall be recorded on the ultimate strength and computed from the area of the base metal section (pounds per square inch).]

PAR. U-69*d*. Revise second section to read:

Tension Tests. [Each full-section tension specimen should fail in the plate if the weld reinforcement is retained, but if failure occurs in the weld metal or along the line of fusion between the weld metal and the plate, then the tensile strength shall not be less than the minimum of the specified tensile range of the plate used.] For the reduced-section tension-test specimens the tensile strength shall not be less than 95 per cent of the minimum of the specified tensile range of the plate used. (THE TENSION TEST OF THE JOINT SPECIMEN AS SPECIFIED HEREIN IS INTENDED AS A TEST OF THE WELDED JOINT AND NOT OF THE PLATE.)

PAR. U-70*c*. Revise first two sections to read:

c Test Specimens. [Two full-section tension-test specimens] Two reduced-section tension-test specimens and two bend-test specimens shall be required from each test plate.

[*Full-Section Tension-Test Specimen.* The shape and dimensions of the tension-test specimen shall be as shown in Fig. U-14 with the weld at the center. Data shall be recorded on the ultimate strength and computed from the area of the base-metal section (pounds per square inch).]

PAR. U-70*d*. Revise second section to read:

"*Tension Tests.* [Each full-section tension specimen should fail in the plate if the weld reinforcement is retained, but if failure occurs in the weld metal or along the line of fusion between the weld metal and the plate, then the tensile strength shall not be less than 90 per cent of the minimum of the specified tensile range of the plate used.] For the reduced-section tension-test specimen the tensile strength shall not be less than 85 per cent of the minimum of the specified tensile range of the plate used. In no case shall the tensile strength be less than 42,000 lb per sq in. (THE TENSION TEST OF THE JOINT SPECIMEN AS SPECIFIED HEREIN IS INTENDED AS A TEST OF THE WELDED JOINT AND NOT OF THE PLATE.)

FIG. U-13. Omit reference to full-section tension-test specimen.

FIG. U-14. Omit.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Oliver Evans

OLIVER EVANS, a Chronicle of Early American Engineering. By Greville Bathe and Dorothy Bathe. Historical Society of Pennsylvania, Philadelphia, Pa., 1935. Cloth, 9 × 11 in., xviii and 362 pages, 48 supp. plates, $12.

REVIEWED BY JOSEPH W. ROE[1]

THIS book is an exceedingly valuable addition to American engineering history. Evans has been a half mythical figure, more or less confused with John Fitch, and thought of as a cantankerous, impractical inventor who died a failure. The fact is that he was unusually practical, clear-headed, the father of modern materials handling, and a successful pioneer in the steam engine. He was certainly an independent, and probably the first, inventor of the high-pressure steam engine. He won his way from poverty to the position of an influential manufacturer, and when he died his estate amounted to about $35,000, a tidy sum in those days.

His reputation for quarrelsomeness comes chiefly from his vigorous defense of his patent rights and his efforts to collect royalties justly due him. Like Eli Whitney he was one of the earliest patentees under our present patent system, and he had the same hard struggle. The Federal patent system was still nebulous and insecure. A judge of the circuit court in Pennsylvania held that any patent was an infringement of public rights and should not be upheld. Whitney, in one of his patent suits, had the greatest difficulty in establishing that a cotton gin had ever been used in Georgia, although at the time of the trial three infringing sets of gins were running so close to the courthouse that the noise of their wheels disturbed the proceedings of the trial. Under such conditions it is not surprising that the situation should get on an inventor's nerves.

Evans was born in Delaware in 1755. He served an apprenticeship as a wheelwright, and invented a card-making machine as early as 1777, but never followed it up. In 1785 he built his first flour mill and began a series of improvements which laid the basis of the whole art of materials handling. He used an endless belt carrying iron buckets arranged to fill with material at the bottom, and empty by gravity into a hopper at the head, which is, of course, our modern bucket elevator. He used pivoted wooden spouts at the discharge of the elevator to deliver the material into selected bins. For horizontal movement, he developed the present scraper conveyor, where flights pulled the material along a trough. He also used a belt conveyor for horizontal movement, without the troughing feature, however, which is a later improvement. When the discharge end was the lower, he utilized gravity to drive it, and called it a "descender." What Evans called a "drill" was the modern screw conveyer, which was not only provided with spiral flights for moving material, but also with interrupted flights and wooden cleats for stirring and breaking it up. His "hopper boy" consisted of a vertical shaft, with cross bars at the lower end provided with flights which spread the meal for drying and slowly worked it in a spiral toward a hole in the center. The angle of the flights was adjustable to vary the time for cooling. In his patents and his various books Evans shows nearly all of the modern materials-handling devices, substantially in their present forms.

The first large mill in which these were incorporated was the Ellicott Mill at Patapsco, Maryland, and they were said to have effected a saving of $30,000 a year. He took out a patent for these improvements in 1790. Washington was one of the first to take out a license under it, and the machinery was installed in his flour mill on the Mount Vernon estate. The last journey Washington ever made was a ride to this mill. It ran for many years after his death, but nothing remains of it now except the foundations, although a movement is in progress to restore it in its original form.

The Materials Handling Division of The American Society of Mechanical Engineers might well make Oliver Evans its patron saint, and honor itself in honoring the man who created that field of engineering.

In 1795 Evans published his "Young Millwright and Miller's Guide," which ran through fifteen editions and was

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translated abroad. The last edition was published in 1860. How many handbooks have surpassed this record of more than 65 years of usefulness? The only one known to the writer is possibly that of Haswell. This record alone would absolve Evans from the charge of being a visionary. Mr. Bathe says that he knows at least one mill owner who has a copy of the "Millwright" in his office to which he occasionally refers even today, considering it still in many respects the most practical work for millers ever published.

In 1804 Evans planned another book to be called "The Young Steam Engineer's Guide," which was intended to be complete and "abstruse." Crippled for the time being by some of his engine ventures, he issued it greatly abridged, with only part of the illustrations planned, and called it the "Abortion to the Young Engineer's Guide." One of his engines described in this book had a cylinder 20 in. in diameter, with a 5-ft stroke, designed for a steam pressure of from 194 to 220 lb per sq in. Remember that this was in 1805. It indicates how far Evans had gone in his work on the steam engine.

As a young man, descriptions of the Newcomen and Watt engines had fallen into his hands, but from the start he began thinking and experimenting along his own lines. He saw the advantage of high steam pressures, and his letters and writings show that he was thinking in terms of heat. He seems to have been free from the dread of high pressures which obsessed Watt all his life. Evans saw instinctively that the "high-pressure," noncondensing engine was best suited to American pioneer conditions, and his influence on early steam-engine practice in this country was comparable almost with Watt's. The two men died within a few months of each other, in 1819. Fulton, who had ordered the engine for the Clermont from Boulton and Watt, clung to the low-pressure type, using only six or eight pounds pressure, and there was a long, hot argument between Fulton and Evans as to the merits of the high-pressure and low-pressure types.

Evans just escaped antedating Fulton by four or five years in the successful application of steam navigation. John Fitch, of course, had a boat in actual operation on the Delaware long before either of them, but it was a clumsy affair and while operable it was not a financial success. In 1802 Evans built an engine and boiler which was sent to New Orleans, together with two mechanics to install it in a boat 80 ft long and 18 ft wide, intended to operate between New Orleans and Natchez. In the spring of 1803, just when all was ready for trial, a flood carried the boat away and left it, jammed in the forest, so far inland as to make it impossible to move it back. To save the investment the engine was taken out and utilized on the spot to operate a saw mill. It was so successful in this that local hand-sawyers, fearing the competition with it, burned down the mill, destroying all the machinery. Had it not been for this train of unfortunate circumstances, it is quite possible that Evans might have won the laurels which came to Fulton.

A few years later, in 1805 Evans performed the spectacular feat for which he is probably the best known. He built near what is now City Hall Square in Philadelphia a flat-bottomed dredge, fitted with steam-driven chain buckets, which he called the "Oruktor Amphibolos," in other words the amphibious digger. It was mounted on removal wheels and fitted with a paddle-wheel at the stern. He advertised his show for several days in the papers, and at the appointed time the boat walked out of Market Street under its own power, to the Schuylkill River, and into the water. The wheels were removed and it then steamed down the Schuylkill and around up the Delaware to the city. This was not the first case of steam navigation, for Fitch and others antedate Evans in that, but it was without doubt the first case in this country of steam propulsion on land.

Some time about 1790 Evans moved to Philadelphia, where he lived and worked the rest of his life. He opened a machine shop and foundry where he built mill supplies and steam engines. In 1807 he was established as a millwright and engineer at the Mars Works, at Ninth and Vine streets, and here he produced flour-milling machinery, steam engines, and pumping engines, which were sold over the entire country. He seems to have been the first regular builder of steam engines and boilers in this country. The development of the high-pressure steam engine, certainly in this country, owes more to him than to any one else, and it would be interesting to run down how far his influence is responsible for the long-stroke engines which have prevailed to this day on our western rivers. His engines seem to have been the first out there, and these western river-boat engines have always preserved the proportions characteristic of his early work.

Mr. Bathe says that there is now nothing left in the way of machinery that can be directly attributed to Oliver Evans. Fortunately, from Evans' books, "The Millwright," and the "Abortion," which were well illustrated for the time, we have a reliable record of much that he did. His theories on thermodynamics and mechanics were as nearly right as the knowledge of his time permitted. His practice was seldom wrong, and his method of thinking was thoroughly sound. Quoting from his "Millwright and Miller's Guide," he gives as the steps involved in the invention, the following:

> Step I. Is to investigate the fundamental principles of the theory, and process, of the art or manufacture we wish to improve.
>
> II. To consider what is the best plan, in theory, that can be deduced from, or founded on, those principles to produce the effect we desire.
>
> III. To inquire whether the theory is already put in practice to the best advantage; and what are the imperfections or disadvantages of the common process, and what plans are likely to succeed better.
>
> IV. To make experiments in practice, upon any plans that these speculative reasonings may suggest; or lead to.—Any ingenious artist, taking the foregoing steps, will probably be led to improvements on his own art: for we see by daily experience that every art may be improved. It will, however, be in vain to attempt improvements unless the mind be freed from prejudice, in favour of established plans.

This has hardly been improved upon in 125 years.

We are all indebted to Mr. and Mrs. Bathe and to the Historical Society of Pennsylvania for this book. It goes back everywhere to original sources and has probably turned up practically all the data still available. Many of these documents are reproduced. The book is beautifully printed, richly illustrated, and the list of acknowledgments in the preface is an indication of the extent and thoroughness of the research which underlies it.

But the book has the fault of one so rich in source material in that it includes, for the sake of accuracy and completeness, much detailed material which is relatively unimportant. Also, it is written on a chronological basis, the years involved appearing throughout at the head of each page. This is convenient if one is looking up a subject on the basis of time, but it breaks up the continuity of a subject which recurs again and again over an extended period. Furthermore, the very completeness of the book makes it bulky and expensive.

The subject is so interesting and worthwhile that it is hoped that the book may be brought out in some cheaper and smaller edition, where the material will be carried through on a subject basis

rather than a chronological one. No one is better fitted to do this than Mr. Bathe, who knows more about Evans than anyone else.

Report Writing

THE PREPARATION OF ENGINEERING REPORTS. By Thomas R. Agg and Walter L. Foster. McGraw-Hill Book Co., Inc., New York, 1935. Cloth, 5 × 7½ in., 192 pp., 44 tables, illus., $1.75.

REVIEWED BY A. C. HOWELL[2]

IF ONE compares reports of today with those written a generation ago, one is made aware that the engineer of today has made great advances in the art of writing and has learned to express himself concisely, clearly, and for the most part correctly. Just such books as the one being reviewed have brought about this change. Indeed, the increased emphasis upon technical writing in colleges, the excellent textbooks now available, and the trained specialists that direct English courses in our engineering schools have all begun to show results in the improved quality of reports and papers in the technical press. In spite of these advances, however, the beginner or one who is called on occasionally for a report often has difficulty in achieving a satisfactory result. This book will lighten the task of such people by furnishing practical help in matters of form and detail.

On the important question of how to develop good style—how to write well—it does not offer much help; indeed it is often a bad example to follow. Nor can any simple formula for attractive engineering writing be presented. But certain rules, if consciously followed, will assist the inexperienced writer. One should never begin writing a sentence until he has it completed in his mind. He should make every word count by cutting out unimportant words, circumlocutions, and repetitions of word or idea. He should avoid monotony by varying his sentences in length, pattern, and form. Finally, he should join his sentences by transitional devices so that his writing flows logically and intelligently from idea to idea.

Dean Agg and the late Professor Foster have produced in this book a simple guide for the engineering-report writer which is in several respects excellent. In it they write, in Lord Bacon's phrase, "what men do, not what they ought to do;" they discuss practice, with illustrations, not theory. Their book is eminently practical, directed squarely at the engineer. Thus it excludes certain types of reports such as business, educational, and sociological surveys; and it includes a rather technical chapter on the use of tables, charts, and diagrams, which is perhaps its most noteworthy feature. Other excellent chapters take up collection of data, and the preparation of form reports, a discussion which is of great practical value because it is more complete than are most treatments of the subject.

The book includes 135 pages of text and 36 pages of style book, a brief bibliography of reports, and a suggested outline for a course in report writing. Unfortunately, one notes a certain lack of proportion in the treatment of topics; for instance, the authors devote 11½ pages to discussion of title pages and only 4½ to letters of transmittal. Similarly, on the comparatively simple matter of abbreviations the authors present 15 rules, containing five negative statements and three exceptions, plus a nine-page table of abbreviations, including the 48 states but only two Canadian provinces, the months of the year but not the days of the week; yet they totally neglect to mention the subject of spelling or plural formation though most style books cover these items.

The simplicity of the book is admirably illustrated by the compact synopsis of the essential characteristics of a good report, in which the authors stress five qualities: Effectiveness in arrangement, emphasis, and authoritativeness in style, completeness in matter, correctness in language, and attractiveness in appearance. But the simplicity of design in the book is marred by an unpleasant style. Two illustrations will indicate this: "In many instances the best preparation is to prepare a list of questions, and to propound them one by one and make notes of the replies that are received." How else than "one by one" could questions be propounded in an interview? Certainly "preparation *is* to prepare!" One "and" is superfluous, and "in many instances" is a circumlocution for *often*.

The authors are fond of the jargon, *cases* and *instances*, words which mar any style aiming at simplicity. The following sentence illustrates other stylistic faults of the book: "In each branch of engineering there are certain fundamental and basic facts that are the working tools of that particular field of professional practice." "Fundamental" is merely a Latin form of the Greek word from which "basic" is derived; the two are synonymous. The repetition of "that" is annoying. The "there is" construction lacks precision. The authors could have saved the reader's time by writing: "Each branch of engineering has certain fundamental facts as working tools in that particular professional field." At least the revision has the merit of conciseness; but a similar lack of conciseness in word choice and sentence structure runs throughout the book. The authors remark that: "Long sentences are likely to lack clearness or to be awkward in construction," yet in their comparatively short text more than a score of sentences run over fifty words. For instance, the first four sentences in chapter 7 contain 60, 70, 44, and 53 words, respectively.

Pages 101, 171, and 175 contain typographical errors, and the list might be increased. The bibliography seems to lack organization. Neither are the reports arranged alphabetically nor are like reports grouped together (Nos. 1 and 59 are both annual reports from the same body). On the whole the material presented in the style book is useful if somewhat complicated by negative rules and confusing exceptions. For instance, after remarking that the only way one can be "reasonably sure" in the use of hyphens is to consult a dictionary, the authors present 22 positive and negative rules and call attention to several exceptions. Surely so formidable a treatment is not very serviceable.

As a guide in the preparation of reports, however, this book will be found helpful and sound in practice.

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Books Received in Library

CALCULUS. By H. H. Dalaker and H. E. Hartig. Third edition. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 276 pp., diagrams, charts, tables, $2.25. Intended for a first course in the subject, this text aims to develop the principles and methods hand in hand with their application to stated problems. This edition has been changed by adding new problems and figures, and rewording some statements more clearly.

ELASTICITY, STRUCTURE, AND STRENGTH OF MATERIALS USED IN ENGINEERING CONSTRUCTION. Part 2, The Equations of Physical Properties and Constants Developed From Molecular, Atomic, Mass, and Gravitational Relations, and Relations of Variation in State and Conductivity Equations. By C. A. P. Turner, 342 Builders Exchange, Minneapolis, Minn., 1935. Paper, 6 × 9 in., 50 pp., tables. Sold as an addenda to part 1 without extra charge. This is the first installment of the second part of Dr. Turner's treatise on elasticity, and is devoted to a discussion of the synthesis of molecular and atomic energy. A method is outlined for calculating the density, specific heat, coefficient of expansion, latent heat, strength, and other physical constants from the atomic weights of the elements.

Engine Auxiliaries, Lubrication, Testing. By J. Vanderdoes, L. H. Morrison, and C. T. Baker. International Textbook Co., Scranton, Pa., 1935. Leather, 5 × 8 in., $2.40. The construction and operation of the auxiliaries of internal-combustion engines, and the installation, lubrication, and testing of these prime movers are described in a simple, practical way.

Engine Bearing Loading. By W. Samuels. Edwards Brothers, Inc., Ann Arbor, Mich., 1935. Cloth, 6 × 9 in., 112 pp., $3. This work offers a new method of solving the problem of engine-bearing loading in four-cycle carburetor engines, as used in automobiles. It is claimed that the method establishes the bearing loads in less time and with greater precision than the methods used heretofore.

Factory Mutuals 1835–1935, being primarily a history of the Manufacturers Mutual Fire Insurance Company, the original of the Factory Mutual Companies during its first one hundred years. Manufacturers Mutual Fire Insurance Company, Providence, R. I., 1935. Cloth, 6 × 9 in., 384 pp., illus., tables, maps. This attractive history of the group of insurance companies known as the "Factory Mutuals" is issued to commemorate the centenary of the original member of the group, the Manufacturers Mutual Fire Insurance Company. The volume opens with a sketch of the early history of insurance, followed by an account of the birth and evolution of these mutual companies, in the development of which Dr. John R. Freeman played so prominent a part. The book contains much of general interest on the development of fire protection, mill-building construction, and automatic systems for extinguishing fires, together with biographical sketches of Zachariah Allen and of John R. Freeman.

First Report on Viscosity and Plasticity, prepared by the Committee for the Study of Viscosity of the Academy of Sciences at Amsterdam. (Verhandelingen der Koninklijke Akademie van Wetenschappen te Amsterdam, Afdeeling Naturrkunde, eerste Sectie, Deel XV, No. 3.) Noord-Hollandsche Uitgevers-Maatschappij, Amsterdam, N. V, 1935. Paper and bound, 7 × 10 in., 256 pp., diagrams, charts, tables; paper 10 fl.; bound, 11 fl. The committee, which was formed in 1932, undertook to gather information upon the phenomena of viscous and plastic deformation as they appear in various domains of science and technology, to study the relations between these phenomena, to propose a suitable nomenclature, and to study methods of measurement. In this first report, which is largely restricted to the phenomenological aspect of the subject, the basic mechanical relations, the experimental investigation of flow properties, the measurement of viscosity, viscosity and plasticity from a technical point of view, the plasticity of metals and other crystalline substances, and viscosity effects in living protoplasm and muscles are discussed.

Graphical Solutions. By C. O. Mackey. John Wiley & Sons, New York, 1936. Cloth, 6 × 9 in., 130 pp., diagrams, charts, tables, cloth, $2.50. This textbook offers an elementary course in methods for the graphical and mechanical solution of equations, intended for use in engineering schools. Stationary adjacent scales, sliding scales, network charts, and alignment charts are discussed, and a final chapter is devoted to the determination of the values of the constants in nonperiodic equations. The mathematics which is used is simple.

Graphic Course of Patentable Inventions. By H. A. Toulmin, Jr. D. Van Nostrand Co., New York, 1935. Paper, 6 × 9 in., 40 pp., tables, $1. The procedure to be followed in caring for a patentable invention, from its conception to its final protection in the courts is explained in this pamphlet. By use of graphic "flow" charts, accompanied by concise paragraphs of explanation, the intricate steps are made clear. The book should be useful to inventors.

Hartmetallwerkzeuge, Wirkungsweise, Behandlung, Konstruktion und Anwendung. By K. Becker. Verlag Chemie, Berlin, 1935. Cloth, 6 × 9 in., 215 pp., illus., diagrams, charts, tables, 18 rm. (13.50 rm. to U.S.A.) This book aims to supply definite practical instruction on the use of tungsten carbide for tools and implements. The design and construction of all varieties of metal-cutting tools are discussed, and the requirements for cutting various materials are considered. A list of German patents and a bibliography are appended. Users of carboloy and other carbides will find the book helpful.

Index to A.S.T.M. Standards and Tentative Standards, January 1, 1936. American Society for Testing Materials, Philadelphia, Pa. Paper, 6 × 9 in., 160 pp. The standards and tentative standards of the Society which were in effect on January 1, 1936, are included in this index, with reference to the publication where they appear. A numerical list is also included, making the index a convenient guide for locating any specification or method of test that has appeared. The publication is furnished free, on written request.

Introduction to the Study of Physical Metallurgy. By W. Rosenhain, revised by J. L. Haughton. Third edition. D. Van Nostrand Co., New York, 1935. Cloth, 5 × 9 in., 368 pp., illus., diagram, charts, $8. In preparing this new edition of Dr. Rosenhain's well-known text, Dr. Haughton has endeavored to maintain the character of earlier editions as far as possible, and only to alter those parts of the book where advances in the subject make changes necessary. The chapters on the thermal study of alloys, the equilibrium diagram, the microstructure and physical properties of alloys, and on typical alloys systems have been rewritten; other chapters have been revised.

Manual of Foreign Patents. By B. Severance. Patent Office Society, Washington, D. C., 1935. Paper, 6 × 9 in., 161 pp., $1. This work, by the chief cataloger of the Patent Office Science Library, will be very useful to every patent searcher. The patents and patent publications issued by foreign governments are accurately listed, with descriptions of their contents, enabling the inquirer to ascertain what is available and how it may be consulted. The work is based on the Patent Office collection. The book also contains an introductory essay, by Arthur Woischek, which contains sound practical advice for the searcher. A glossary of foreign patent terms and a price list of publications are appended.

Metals and Alloys, Cumulative Index of Metallurgical Abstracts published in Vols. 3–5, January, 1932 – December, 1934. Reinhold Publishing Co., New York, 1935 Cloth, 6 × 11 in., 272 pp., $10. This index provides a convenient key to approximately twenty thousand articles on metallurgy and allied subjects which were abstracted in *Metals and Alloys* during the years 1932 to 1934. The abstracts were indexed by subject and by author, and the index will be found to be of great convenience to workers in this field.

Mitteilungen aus den Forschungsanstalten GHH-Konzern, Bd. 4, Heft 3, December, 1935. Beiträge zur angewandten Spektrographie in metallverarbeitenden Industrien, by G. Heidhausen; Die neuzeitliche Dampffördermaschine, by E. Nalbach. V.D.I. Verlag Berlin. Paper, 9 × 12 in., pp. 59–82, illus., diagrams, 2.70 rm. The first paper in this issue describes the plan and equipment of the spectrographic room in the research department of the Nürnberg works of the Maschinen-Fabrik Augsburg-Nürnberg, planned for practical testing. The second paper discusses developments in steam hoisting engines and the comparative merits of steam and electric hoisting machinery. The author refutes certain criticisms of the first type.

Outposts of Science. By B. Jaffe. Simon and Schuster Co., New York, 1935. Cloth, 6 × 10 in., 347 pp., illus., diagrams, $3.75. Readers who wish an authoritative, readable account of modern achievements in some important fields of physics and biology will find this an entertaining and stimulating work. Mr. Jaffe's report is based upon a tour of important American research laboratories, and interviews with leading investigators. His skill in presenting science in an entertaining way without sacrificing accuracy is evident throughout the book. A useful bibliography is included.

Principles of Mechanism. By F. Dyson. Second edition. Humphrey Milford, London; Oxford University Press, New York, 1935. Cloth, 6 × 9 in., 323 pp., diagrams, charts, tables, $4.25. This text aims to give a comprehensive presentation of the fundamental principles that apply to the moving parts of machines, adapted to the needs of students of engineering. Many worked-out examples of problems in velocity, acceleration, gearing, friction, belting, flywheels, governors, balancing, etc. are given, together with a large number of problems for solution by the student. The text is in general that of the previous edition, but sections have been added on viscous friction and on controlling-force diagrams for governors.

Standard Practices published by Diesel Engine Manufacturers' Association, printed and distributed by Diesel Publications, 192 Lexington Ave., New York, 1935. Cloth, 6 × 9 in., 162 pp., diagrams, charts, tables, $2. This volume contains the standard practices and definitions adopted by the Association, together with information on the cost of Diesel power, the selection of engines, the construction of power plants, and the construction and erection of engines. Consideration is also given to speed regulation, fuel storage and handling, lubrication, cooling, electric equipment, and critical speeds. A model specification for purchase is included and a standard code for field tests. The book deals primarily with heavy-duty low-speed and medium-speed engines for power plants.

THE PRESIDENT'S PAGE

Support the American Engineering Council

WILLIAM L. BATT

THE American Society of Mechanical Engineers has appropriated $9000 this year to the support of the American Engineering Council.

This looks like a tidy sum of money, but to each individual member it amounts to only 75 cents a year.

Is it worth 75 cents a year to you to support the Council?

Is it worth 75 cents a year to you to cooperate with 60,000 other engineers in maintaining an "engineering embassy" in Washington, thus unifying the engineering profession in its contribution to national public affairs?

Is it worth 75 cents a year to you to have in Washington a place where you can go or write for information on government activities that may be of great importance to you?

Is it worth 75 cents a year to you to support active public affairs committees of the Council that examine, from the point of view of the best interests of the public and of engineers, all Congressional bills in which engineering interests are involved?

Is it worth 75 cents a year to you to maintain a point of contact between government departments in Washington and the engineering profession so that members of Congress and government officials may quickly get expert advice on technical matters affecting their work?

An affirmative answer depends on the effectiveness with which the Council carries out its functions—some of which I have suggested in these questions. You can convince yourself on these points by reading the American Engineering News from Washington which appears every month in the "What's Going On" section of MECHANICAL ENGINEERING (pp. 269 and 270 of this issue).

If you visit Washington, call at the "Washington Embassy," the headquarters of the American Engineering Council, at 744 Jackson Place, and meet Frederick M. Feiker, executive secretary, and his staff. And if you have business with some of the government departments, ask them what they think of the American Engineering Council. I predict that you will be convinced that your 75 cents is well spent.

W L Batt.

WHAT'S GOING ON

Including News of A.S.M.E. Affairs

This Month's Authors

EVERY ONE likes to see CHARLES F. KETTERING, president and general manager of the General Motors Research Corporation, unfold his long limbs behind a dinner table, and hear him launch into one of his instructive and witty after-dinner talks. There is usually no paper, no notes, just extemporaneous talk—touching always somewhere on research; but when there is a stenographer present, as there was at the dinner in Chicago when Mr. Kettering rose to respond to the bestowal on him of the Washington Award, a record can be made for the benefit of those who are not privileged to be among the guests. Such was the origin of the paper "Research and Social Progress," published this month as the leading article. Those who have heard Mr. Kettering, who is a member of the A.S.M.E., will be able to clothe the cold, printed words with the brilliant raiment of his characteristic gestures and inflections. It is superfluous to list his many achievements. We pay him unconscious homage every time we place foot on the starter and turn the car down a dark road, made safe for driving by brilliant headlights. He is one of those incorrigible and fertile inventors who has never learned a lot of things that are not so and whose bright lexicon, in the phraseology of the old saw, contains no word meaning "can't."

H. H. COUCH, captain, Matériel Division, U. S. Army Air Corps, Wright Field, Dayton, Ohio, is the author of the article on "Propeller Crankshaft-Vibration Problems." Captain Couch received the degree of B.S. from the University of Michigan in 1922, but he had previously served with the Army during the World War as second lieutenant in the Air Service. Upon his graduation he became connected with the Curtiss Aeroplane and Motor Company in the design of propellers. He returned to the Army in 1924 where he completed the course for airship pilot and balloon observer. He was promoted to the rank of first lieutenant in 1930 and sent to Wright Field, where he has been connected with the propeller unit of the aircraft branch of this Division. He was advanced to the rank of captain in 1935 and now holds the position of director of propeller design and test laboratory of the Matériel Division, and is responsible for the development of the present technique of making vibration analyses on aircraft propellers.

A. W. SCHNEIDER, author of "Finishing Internal Surfaces," is a graduate of the University of Cincinnati, in mechanical engineering. He worked with various machine-tool plants in Cincinnati and later spent several years in consulting work with the Charles Bedaux Co., New York, N. Y. For about six years before becoming associated with the Heald Machine Co., Worcester, Mass., in the sales-engineering department, Mr. Schneider was works manager of the Reed-Prentice Corporation.

It is always a privilege to publish papers by junior members of The American Society of Mechanical Engineers as proof of the virility and originality that younger men possess entitling them to the respect of their older colleagues. The gas calorimeter which RAFAEL W. KEITH describes in this issue was developed by him in the mechanical-engineering laboratories of Cornell University. Mr. Keith is at present head of the Keith Independent Research Service of Ithaca N. Y.

The widely and favorably known vocational-training work of the metal trades of Milwaukee and the Falk Company provided the background of practical experience in teaching which C. J. FREUND has been applying so successfully as dean of the college of engineering of the University of Detroit. It has also provided the basis for Dean Freund's views on leadership and scientific scholarship which are set forth in the article published this month. In addition to being a member of the A.S.M.E. Dean Freund is also a member of the American Foundrymen's Association, the National Metal Trades Association, and the Society for the Promotion of Engineering Education, all organizations that have long been actively interested in vocational training.

MESSRS. FRITZ and HAMILTON, respectively superintendent, Eastern Region, and System Maintenance Superintendent, Transcontinental & Western Air, Inc., gained their early experience in aeronautics by practical flying and airplane repair and maintenance. Both have had colorful careers typical of those afforded by a rapidly developing industry in which resourcefulness and technical skill of an unusually high order are paramount requisites. Their paper, originally presented at the A.S.M.E. National Aeronautic Meeting at St. Louis last October, is evidence of the application of these qualities to the service and safety of the air-traveling public.

With a background of engineering and shop experience, acquired, after his education at Swarthmore and the University of Wisconsin, with the J. C. Busch Co., the Bucyrus Company, and the Oilgear Company, of Milwaukee, JOHN P. FERRIS, member, A.S.M.E., was associated with the executive council of the State of Wisconsin, where he became interested in a notable investigation of the possibilities within that state for local industries, the development of latent resources, coordination of state agencies on land-use planning, and the formulation of land-use programs. At present Mr. Ferris is a member of the Agricultural Industries Division of the Tennessee Valley Authority.

H. A. FREEMAN is acting head of the department of economics at the Massachusetts Institute of Technology. This is the second of Mr. Freeman's contributions to this series, the other having appeared in the July issue of last year.

A.S.M.E. Dallas Meeting, June 15–20

THE North Texas Section of The American Society of Mechanical Engineers in cooperation with the professional divisions of the Society has arranged a splendid technical program for the 1936 Dallas Meeting, June 15–20. The technical sessions will be held Wednesday, Thursday, and Friday, with Saturday given over to Engineers' Day at the Texas Centennial Exposition.

One management session has been arranged with three excellent papers on decentralization of industry, Texas industrial development, and municipal management. At the railroad-locomotive session papers on burning of oil and one on lubrication problems will be presented. There will be three or four sessions on petroleum, covering production problems at the wells, heat-transfer, and problems relating to pressure-vessels and pipe-lines, and one session in cooperation with the Machine Shop Practice Division on design of oil-field equipment.

A strong power program has also been arranged that will consist of two or three sessions covering such subjects as natural-gas fuel for central stations, operating experiences with pulverized lignite, operating features of a 1450-lb steam power plant, automatic combustion control for the burning of certain types of fuel, and boiler-water problems. A session to be held jointly with the Process Industries Division will be devoted to power problems in the sulphur industry. There will also be a session on air conditioning. The Process Industries Division is sponsoring a session of its own covering mechanical problems in the sulphur and potash industries, and will cooperate in other sessions with the Power, Management, and Petroleum Divisions. The hydraulic session will provide papers on centrifugal pumping, irrigation pumping, and engineering features of Dennison Dam. A round-table symposium on control and instruments, sponsored jointly by several divisions and the Fluid Meters Committee, will contain several papers on industrial regulators, flow of saturated water through orifices, and fluid-meter research.

In addition to these sessions several others of general technical interest have been planned.

Among the subjects to be treated are the development and improvement in cast-iron pipe, production of helium, mass transportation in cities, manufacture of carbon black, and the development of cotton-picking machinery. There will also be papers of general interest on vocational training, covering the national training program and the training program in the Southwest.

A number of plant-inspection trips are being arranged.

The Committee on Meetings and Program is planning to present a distinguished European engineer to give the Calvin Rice Memorial Lecture in connection with the meeting.

A.S.M.E. Dallas-to-Mexico Tour

FOLLOWING the Semi-Annual Meeting of The American Society of Mechanical Engineers, to be held in Dallas, Texas, June 15–20, there is offered an opportunity to arrange a remarkable and inexpensive tour to Mexico. The Committee on Meetings and Program will be glad to hear from members who might wish to go on such a trip.

The tour would be planned on an "all-expense" basis of eight-days' duration with Mexico City as headquarters. Special sightseeing trips would be arranged to San Antonio, Texas, to see the Alamo, cradle of Texas' liberty, the ancient missions, Mexico City, one of the wonder cities of the World, Puebla, Cholula, San Juan Testihuacan, Guadalupe, Xochimilco, and Cuernavac, the "Atlantic City" of Mexico.

This splendid two-weeks' vacation would include a day through the Texas oi fields, four days for the meeting and the Texas Centennial Exposition, and the Mexico trip to top it off. If interested, please communicate at once with the Secretary, A.S.M.E., 29 West 39th Street, New York, N. Y.

A.I.E.E. Nominations

THE National Nominating Committee of the American Institute of Electrical Engineers, consisting of members from various parts of the country, has nominated the following official ticket of candidates for the offices becoming vacant August 1, 1936:

For president, A. M. MacCutcheon, engineering vice-president, Reliance Electric and Engineering Co., Cleveland, Ohio. For vice-presidents, A. C. Stevens, General Electric Co., Schenectady, N. Y.; O. B. Blackwell, Bell Telephone Laboratories, Inc., New York, N. Y.; C. Francis Harding, Purdue University, Lafayette, Ind.; L. T. Blaisdell, General Electric Co., Dallas, Tex.; and C. E. Rogers, Pacific Telephone & Telegraph Company, Seattle, Wash. For directors, K. B. McEachron, General Electric Co., Pittsfield, Mass.; C. A. Powel, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.; and R. W. Sorensen, California Institute of Technology, Pasadena, Calif. For national treasurer, W. I. Slichter, Columbia University, New York, N. Y.

Foundrymen and Engineers Meet in Birmingham

WITH a registered attendance of 400 foundrymen and engineers from the southern states, and with some representatives from cities of the north, the fourth joint foundry-practice meeting, sponsored by the Birmingham Section of The American Society of Mechanical Engineers, with the American Foundrymen's Association cooperating, was held at the Tutwiler Hotel, Feb. 27 and 28, 1936. Attendance greatly exceeded the previous mark of 250, and the technical sessions were pronounced the most interesting and valuable held. This gathering of foundrymen was made the occasion for the formation of a chapter of the A.F.A., which is to be known as the Birmingham district chapter. L. N. Shannon, member, A.S.M.E., vice-president, Stockham Pipe Fittings Co., Birmingham, was elected chairman.

The two-day conference closed with a banquet which some 300 engineers and foundrymen attended. Joseph W. Eshelman, chairman of the Birmingham Section of the A.S.M.E., presided, and W. Carson Adams acted as toastmaster. The guest speaker upon this occasion was W. L. Batt, president of The American Society of Mechanical Engineers and president of SKF Industries, Inc., Philadelphia.

Mr. Batt, said he was greatly impressed with the possibilities of the South to become *the* section of the country in a few years, with its climate, mineral resources, and proximity to the seaports of the South, which offered splendid possibilities for manufacturing. He further said that he was impressed by the splendid engineering schools which have fine equipment and instructional staffs. Mr. Batt defended the engineering profession from the charge of being responsible for the present unemployment situation. The changes brought about by engineers, he said, have created more jobs than have been displaced. The effect of the machine age has been to make work, not unemployment. Unemployment, he said, has been caused by failure to adjust correctly the problems of distribution and production. Mr. Batt said further that the problem of unemployment could be more easily solved if employers would apply the golden rule in their relationship with their employees.

Mr. Eshelman, on behalf of the A.S.M.E., presented a gavel to Mr. Shannon, chairman of the newly formed chapter of the A.F.A., and with it the best wishes of the A.S.M.E. section and hopes for continued cordial cooperation between the two organizations like that which had made the meetings possible in the past.

At the luncheon on Thursday, James L. Wick, Jr., member, A.S.M.E., vice-president of the A.F.A. and president, Falcon Bronze Co., Youngstown, Ohio, presented a message of greeting from the A.F.A. to the group and discussed management of a foundry in relation to technical advancements being made. He stressed the need for employers to reward employees in proportion to the returns of the business. He further stressed the advantages to be gained by management in taking advantage of the information being presented in papers before the Association, in satisfying customers with improved products. He stated that he believed that sales management had not measured up to improvements in products and production methods.

Oil and Gas Power Meeting at Ann Arbor in June

THE NINTH National Oil and Gas Power Meeting under the auspices of The American Society of Mechanical Engineers will be held at the University of Michigan, Ann Arbor, Mich., in June under the joint sponsorship of the Oil and Gas Power Division and the Detroit Section of the Society.

The program of the meeting will follow the arrangements that have, in the past, been so successful when this meeting has been held on a college campus. Prof. C. W. Good, of the University, is organizing the local arrangements, and Lee Schneitter, L. H. Morrison, Harte Cooke, E. J. Kates, and L. M. Goldschmidt are arranging the program and exhibits for this meeting of the Oil and Gas Power Division.

Annual Meeting, Louisiana Engineering Society

ON JANUARY 24 and 5 the Louisiana Engineering Society, with which the New Orleans Section of The American Society of Mechanical Engineers is affiliated, held its annual meeting with headquarters at the St. Charles Hotel, New Orleans, La. James M. Todd, member of the A.S.M.E. Council, acted as chairman of the general committee.

Meetings by sections of various local engineering groups, including the A.S.M.E., and a conference of about 150 engineering students and 20 older men, under the supervision of George R. Hammett, member, A.S.M.E., were features of the program for Friday morning. Friday afternoon was devoted to inspection trips, and the evening to a public lecture on the Mississippi River flood-control project, by John Klorer, chief state engineer of Louisiana.

Among the technical papers presented at the Saturday sessions was one by William Monroe White, member, A.S.M.E., on "Manufacture of Large Machinery."

Iron and Steel Engineers Meet, April 22–23

AS PART of the program of the Association of Iron and Steel Engineers' Annual Spring Engineering Conference to be held in Youngstown, Ohio, April 22–23, will be an inspection trip to the new hot-strip mill of the Carnegie-Illinois Steel Corporation recently completed and put into operation at McDonald, Ohio. Preceding this inspection trip will be an evening and morning technical session, at which will be discussed many important steel-making problems of today.

Midwest Power Conference, Chicago, Ill., April 20–23

FOR the first time in several years the Midwest Power Conference will be held at the Palmer House, Chicago, April 20–23. It is being sponsored by the Chicago Sections of various societies including The American Society of Mechanical Engineers. The Conference opens Monday morning April 20 with an address of welcome by Mayor E. J. Kelly, of Chicago. The Monday sessions, and those on Tuesday, Wednesday, and Thursday morning, will be held at the Palmer House. The sessions on Wednesday and Thursday afternoon are to be at the International Auditorium where an exhibition of power-plant equipment and accessories is to be held.

There will be a membership registration fee of $1 which will entitle those registering to reduced return fare, provided a railroad certificate has been obtained at the time the going ticket was purchased.

A detailed program follows:

MONDAY, APRIL 20

Registration, All Day

8:00 a.m. **Palmer House**

Address of Welcome, by Mayor E. J. Kelly of Chicago

10:30 a.m. **Palmer House**

Opening Session

Address by Frank D. Chase

2:00 p.m. Power Economics

Trends in Research, by C. F. Hirshfeld
Interchange of Power and Steam Between Industries and Utilities, by William A. Hanley
Trends in Power-Plant Operation, by William Benson Mayo

TUESDAY, APRIL 21

9:30 a.m.

Power-Plant Buildings and Dams

Influence of Earthquake Hazard on Power Plants, by P. E. Stevens
Fort Peck Dam, by Claude H. Chorpening

Electrical Problems

This session will comprise two papers devoted to electrical problems, one by a representative of the General Electric Co., and the other by an engineer of the Westinghouse Electric & Manufacturing Co.

Diesel and Internal-Combustion Engine Power

Film: "Romance and Progress of the Diesel Engine." Courtesy of Hemphill Diesel School
Heavy-Duty Portable Diesel Engines for Construction and Contracting, by G. E. Spain
Large Diesel-Engine Mechanical Developments, by Max Rotter
Fuels for Diesels, by E. W. Roby

12 m. Luncheon Meeting, Chicago Engineers' Club

Speaker: Capt. Claude H. Chorpening, U. S. Army

WEDNESDAY, APRIL 22

9:30 a.m.

Refrigeration

Air-Conditioning Application, by Zieber and Nicoll
Refrigerants, by Harry D. Edwards

Fuels—Classification of Coals by Use Value

Use Value of Coal for Steam Generation, by C. C. Wilcox and John Nash
Some Characteristic of Midwest Coals, by H. L. Olin
Simplification of Coal Sizing, by Joseph Harrington

Power Piping and Welding

Valves, by H. H. MacMillen
Power-Plant Piping
Welding of Alloy Steels and Pipe, by J. R. Dawson

1:30 p.m.

Engineering Economics and National Power

Executive and Engineering Phases of Government Projects
Private Enterprise Viewpoint of Engineering Economics

7:00 p.m. **Banquet Palmer House**

Speaker and Program to be announced later.

THURSDAY, APRIL 23

9:30 a.m.

Power Plant Technics

Trend of Large High-Pressure High-Temperature Boiler Design, by F. H. Rosencrants
Water Conditioning for High-Pressure Steam Generation, by R. E. Hall
Turbine Operation, by A. C. Flory

Fuel Utilization

The Value of Proper Furnace Equipment to Power-Plant Economy, by M. K. Drewry
What Modern Fuel-Burning Equipment Means to the Industrial Plant, by John C. Kuhns

Power Transmission to Machinery

Modern Group Drives, by W. R. Clendenning
High Starting Torque and Overload-Release Devices, by William Stanier
Direct-Motor Drives for Machinery Application, by F. E. Butterfield

Fuel Economy and Controls

2:00 p.m.

Coordinating the Operation of Boiler Auxiliaries, by A. F. Spitzglass and G. K. O'Connor
Superimposing of High Pressures on Existing Plants, by Frank Clark
Modernizing Old Plants, by a representative of the Federal Housing Administration

A.E.C. News From Washington

CURTAILMENT of the number of projects and of funds and of staffs occupies the attention of the heads of various Federal departments and bureaus. This trend toward reducing government expenditures, while not yet large enough to affect materially the total budget, is in part brought about by the desire to decrease government expenditures and in part by the fact that overimaginative enterprises are being squeezed out of the final program of accomplishment in the facing of facts. "Reform" and "social objectives" are still major factors, but "economy" and "practicality" are offsetting factors of increasing weight in determining government policy.

These trends are evident in several directions and the following inventory of legislation or executive action are typical:

RURAL ELECTRIFICATION

Rural electrification now has a support of special legislation. The new Act provides $42,000,000 a year for ten years for the construction of transmission lines into rural areas and the construction of generating plants where an adequate supply of electricity is not available, or where it cannot be obtained at what are thought to be reasonable prices. However, present Rural Electrification Administration commitments run between five and six million dollars for about 5000 miles of transmission lines to take care of 17,500 farm families. Money for these extensions is loaned at 3 per cent for 20 years. With few exceptions, these new lines are interconnected with privately owned utilities for their supply of electricity. This trend, both in volume and in method, is following principles and recommendations earlier made by American Engineering Council committees and staff to the Rural Electrification Administration.

RURAL RESETTLEMENT ADMINISTRATION

Rural resettlement boils down to the following new projects actually in the work: Beltsville (or Berwyn), Md., sometimes called "Tugwell Town;" the project in Cincinnati, Ohio; two projects in New Jersey, one at Bound Brook and one at Hightstown; one in Champlain, Ill.; two other projects are in the drawing-board stage, one in Milwaukee, Wis., the other, known colloquially as the "Dust Bowl" project, located in the area where Kansas, Oklahoma, Colorado, New Mexico, and Texas are contiguous states. In addition, earlier projects started under the FERA which have been picked to be finished are Cherry Lake, Fla.; Red House, Charleston, W. Va.; Pine Mountain Valley project, Warm Springs, Ga.; Mississippi county project in Arkansas; and the Matanooska Valley project in Alaska.

These projects however constitute the smallest part of the work of the Rural Resettlement Administration, there being two other major objectives; first, the purchase of submarginal land and second, rural rehabilitation. Seventy-three projects are under way for the purchase of submarginal land. Rural re-

habilitation in the form of supervised credit for farm families on everything from seeds to a home is active.

FEDERAL HOUSING ADMINISTRATION

The proposal to coordinate various agencies associated directly or indirectly with housing has made little progress, due probably to the lack of consistency in common policy between the agencies. One of the agencies, the Federal Housing Administration seeks changes in legislation which will provide for greater freedom of private capital to invest in small houses. Opposition to changes are based on the fear of a run-a-way boom in residence building, the beginnings of which are already noticeable in some communities.

HEARINGS ON PATENTS

The House Committee on Patents, after securing much testimony on such questions as patent pools, has recently devoted its hearings to questions of copyright protection for authors and composers. There is little indication that any fundamental changes in patent legislation will be passed this year.

NATIONAL RESOURCES COMMITTEE

The National Resources Committee, known originally as the National Planning Board, has been seeking legislation making possible the creation of a planned approach to the development of our natural, as well as human, resources. The hearings held before the Land Policy Committee of the House were not friendly, perhaps because it is difficult to get Congressmen to understand what is meant by "human resources." The American Engineering Council has expressed itself as in sympathy with certain of the objectives of the National Resources Committee, particularly those objectives which seek to coordinate Federal and state relations to such practical questions as water resources, flood control, and coordinated development of mineral resources. One simple objective recommended by the Council's Committee on Water Resources, namely to set up a board of water resources, which would serve as a clearing house for factual information on this subject, has had the approval of the members of the National Resources Committee and of its Subcommittee on Water Resources. Similarly, the proposal for a basic mapping program has had the approval of the Water Resources Committee. In brief, it would seem that it is possible to secure favorable consideration of a planned approach to the coordination of the orderly development of our "natural resources." When the word "natural" is supplanted by "national," and "human" as well as "material" resources are included, there apparently results a confusion of tongues.

COMMISSIONER OF RECLAMATION APPOINTED

Secretary Ickes has appointed John C. Page, acting commissioner of the Bureau of Reclamation. Mr. Page has been chief of the Engineering Division of the Bureau since October 1, 1935, when Dr. Mead transferred him from Boulder Dam to Washington. His age is fifty-nine. He is a graduate in civil engineering of Nebraska and Cornell and has been in reclamation since October 1, 1909. Mr. Page's appointment, while not yet confirmed by the Senate, fulfills the requirements set forth by President Potter in his letters to the President and to the Secretary of the Interior, urging that an engineer of experience be appointed and it is, moreover, in line with the Council's recommendations upholding the merit system in Federal employment.

SIDELIGHTS ON THE MERIT SYSTEM

The House Committee on Appropriations, in passing upon the budget for the Bureau of Foreign and Domestic Commerce of the Department of Commerce, set an extraordinary precedent by recommending that any new employees to the Bureau, needed to perform work under the appropriations, should be drawn from present or past employees. Many highly trained career men were dropped from this Bureau at the beginning of the present administration and it would appear that the congressional committee action offered the opportunity to reconsider them for employment. On the face of it, this seems to be a victory for the Merit System which the Council endorses.

STREAM POLLUTION

The American Engineering Council transmitted to the chairman of the Senate Committee having under consideration new legislation for preventing stream pollution, the recommendations of its member society, the American Society of Civil Engineers, and also a digest of an earlier report of the Council on the same subject supporting the resolutions of the A.S.C.E. In brief, the Council stated that no further Federal laws were needed for Federal control of stream pollution. It urged the consideration of interstate compacts as the most practical way to meet such problems as lie outside the jurisdiction of a single state.

WATERWAY CLEARANCE

To the Bureau of Engineers of the U. S. Army was transmitted a request to appoint a properly constituted committee for the consideration of the whole subject of waterway clearances. Resolutions to this effect were forwarded by our member organization, the American Society of Civil Engineers, which was also supported by the American Association of Port Authorities.

GOVERNMENT EMPLOYMENT

As employees of older emergency agencies are released, they are transferred to the newer agencies. A Transfer Bureau has been created to handle such cases.

Southern Industrial Show at Greenville, S. C., April 6–11

ANNOUNCEMENT has been received of the Southern Industrial Show to be held in Textile Hall, Greenville, S. C., April 6–11. The exhibition will include, the announcement states, boilers, engines, generators, water wheels, elevators, heating, ventilating, refrigerating, air-conditioning, water, sewerage equipment, light machinery, tools, accessories.

Engineers Report on Professional Development

PUBLICATION of the third annual report of the Engineers' Council for Professional Development makes available to engineers and educators a record of the activities of this body. It provides authentic information on the organization, purposes, policies, personnel of the Council, and the work of its four major committees on student selection and guidance, engineering schools, professional training, and professional recognition.

The 36-page annual report contains a list of the participating bodies and their representatives for 1935–1936, the report of C. F. Hirshfeld, Chairman of E.C.P.D. for 1935 committee reports, the charter and rules of procedure of E.C.P.D., the policies adopted by E.C.P.D. since its formation, a brief report on finances, and committee personnel for 1935–1936.

Chief interest attaches to the four committee reports. The report of the Committee on Student Selection and Guidance, R. L. Sackett, dean of the College of Engineering, Pennsylvania State College, deals principally with tests designed to supplement methods of selecting students for engineering colleges.

Plans for putting into effect its program of accrediting engineering schools are discussed in the report of the Committee on Engineering Schools, Karl T. Compton, president, Massachusetts Institute of Technology, chairman.

An appendix to the report of the Committee on Professional Training, Robert I. Rees, assistant vice-president, American Telephone and Telegraph Company, chairman, contains an announcement of a selected bibliography of engineering subjects with samples from the civil-engineering section, covering selected books on bridges, concrete, construction materials, foundations, highways, hydraulics, mechanics of materials, railroads, sewerage, and sewage disposal. Other sections of the bibliography will cover mathematics, physics, chemistry, aeronautical engineering, chemical engineering, electrical engineering, industrial engineering, mechanical engineering, metallurgical engineering, and mining engineering.

A second appendix to this report presents a preliminary survey of university extension facilities, including a general description of the scope of the courses included in the survey and a list of the educational institutions giving these courses through class-room and correspondence study. A suggested operating program for the professional development of junior engineers comprises a third appendix to this report.

Among the subjects the report of the Committee on Professional Recognition, C. N. Lauer, president, Philadelphia Gas Works, chairman, deals with the subject of registration of engineers, and includes, as an appendix, a digest of the engineer-registration laws in 35 states.

The Engineers' Council for Professional Development is a conference of engineering bodies organized to enhance the professional status of the engineer through the cooperative support of those national organizations directly representing the professional, educational, and legislative phases of an engineer's

life. The participating bodies are: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society for the Promotion of Engineering Education, American Institute of Chemical Engineers, National Council of State Boards of Engineering Examiners.

Charles F. Scott, chairman, Connecticut State Board of Registration, is chairman of E.C.P.D., and George T. Seabury, secretary, American Society of Civil Engineers, is secretary. Copies of the third annual report may be obtained at nominal cost by addressing The Engineers' Council for Professional Development, 29 West 39th Street, New York, N. Y.

Annual Report, P.E.C.U., 1934–1935

THE following report, slightly abridged, of the operations of the Professional Engineers' Committee on Unemployment for the fiscal year October 1, 1934, to October 1, 1935, was prepared by C. E. Beam, executive secretary. Members of the executive committee, P.E.C.U. are William R. Smith, Chairman, C. R. Beardsley, Clinton Bernard, V. T. Boughton, and J. N. Landis.

During the fourth year of operation the Professional Engineers' Committee on Unemployment has continued, as in the past, to be the principal agency for placing engineering and supervisory personnel on emergency-work programs in the Metropolitan area. It has also continued to be the agency to which technical men have looked primarily for emergency assistance.

The Works Division under CWA and the present WPA extensively utilized the facilities of P.E.C.U. At the request of General Hugh Johnson, when he was New York Administrator for WPA, the P.E.C.U. became in fact an official agency of the WPA and the National Reemployment Service in filling engineering and supervisory requisitions.

REGISTRATIONS

The Registration Bureau was particularly active during the summer and early fall due to the effort of the Works Division of the WPA to place all unemployed to work before the end of the year. The records of the Registration Bureau show the following for the year's operations:

Applicants	2147
Rejections	408
Registered	1739

In addition to asking for assistance in the placement of engineering personnel, the Works Division asked P.E.C.U. to assist in the selection of a large number of men for positions requiring supervisory and skilled personnel, not engineers. Some 1600 of these men were recommended on requisitions as noted at the foot of Table 1 giving total registration classified by the various society memberships.

TABLE 1 TOTAL REGISTRATIONS

Society membership	Oct. '31 to Oct. '32	Oct. '32 to Oct. '33	Oct. '33 to Oct. '34	Oct. '34 to Oct. '35	Total reg.	Percentage of total registration
A.S.C.E.	240	340	291	110	981	8.8
A.S.M.E.	357	516	309	89	1271	11.6
A.I.E.E.	212	259	154	52	677	6.2
A.I.M.E.	35	49	22	11	117	1.2
S.N.A.&M.E.	..	10	4	1	15	0.2
Former members	..	112	106	23	241	2.2
Nonmembers	1349	1729	3131	1453	7662	69.8
W.S.E.	4	..	..	..	4	..
Total	2197	3015	4017	1739	10,968	100.0
Special registrants	1620					

TABLE 2 PLACEMENTS

Society	Oct. '31 to Oct. '32	Oct. '32 to Oct. '33	Oct. '33 to Oct. '34	Oct. '34 to Oct. '35	Grand total placed
A.S.C.E.	204	149	324	235	912
A.S.M.E.	277	228	318	142	965
A.I.E.E.	173	113	142	70	498
A.I.M.E.	33	23	24	11	91
S.N.A.&M.E.	..	4	4	1	9
Former members	..	36	99	47	182
Nonmembers	648	525	2183	1847	5203
W.S.E.	4	..	..	..	4
Total	1339	1078	3094	2353	7864
Special registrants	391				

PLACEMENTS

The total number of placements in the four years of operation represents 72 per cent of the registrations. Owing to a diminished supply of technical men the placements for last year represent 135 per cent of the year's registrations. While the work of placing engineers on emergency operations has decreased materially, the WPA has asked the assistance of P.E.C.U. in confirming the qualifications of technical men to fill positions in industry and other lines of regular employment. Also P.E.C.U. has assisted the National Reemployment Service in the preparation of manuals for use in selecting personnel in the highway and other construction fields. The P.E.C.U. has also been active in endeavoring to establish appropriate rates of pay for engineers on WPA projects both in New York and New Jersey. It has also been instrumental in obtaining suitable ratings, reratings, or transfers in many individual cases.

Table 2 gives a detailed statement of placements for each year since organization.

FUNDS

The work of P.E.C.U. has been made possible only through voluntary contributions largely from members of the national engineering Societies. Although the contributions have decreased each year, the necessity for funds has likewise fortunately diminished, and P.E.C.U. has been able to function effectively.

The employment picture for engineers has changed materially during the past year due to opportunities in industry and the more permanent Governmental operations. Unfortunately, however, many engineers are still engaged in emergency work programs of uncertain tenure. It is hoped, however, that opportunities in private and Federal long-range undertakings will be able to absorb these engineers as they are released with the shrinkage of temporary work. There is still a definite need, therefore, to continue P.E.C.U. for some time in the future.

The balance on hand at the end of the year totaled $5198.72, which is sufficient only to carry on for about four months at the present rate. There is need, therefore, for additional funds.

Following is a tabulation of Receipts and Disbursements for the year ending September 30, 1935:

RECEIPTS

Contributions, Oct. 1, 1934, to Oct. 1, 1935	$14,566.75
Interest and repayments on loans	849.82
Balance on hand, Oct. 1, 1934	7,915.59
	$23,332.16

DISBURSEMENTS

Relief payments	$15,199.00
Loans	776.00
Social service	722.50
General and office expenses	1,435.94
	$18,133.44
Balance on hand, Oct. 1, 1935	5,198.72
	$23,332.16

Tables 3, 4, and 5, which appear on the following page give, by years, a classification of contributions, number of contributors, and amounts per contributor.

LOANS

The Loan Committee and the Social Service Department of the P.E.C.U. have been able to render an exceptional service to members

TABLE 3 TOTAL CONTRIBUTIONS BY YEARS

Society	(1) Oct. '31 to Oct. 32	(2) Oct. '32 to Oct. '33	(3) Oct. '33 to Oct. '34	(4) Oct. '34 to Oct. '35	Total Oct. '31 to Oct. '35
A.S.C.E.	$ 34,577.38	$17,726.27	$ 6,780.41	$ 5,002.25	$ 64,086.31
A.S.M.E.	25,312.60	12,229.46	7,005.15	3,933.00	48,480.21
A.I.E.E.	22,522.62	14,230.66	5,948.25	3,452.00	46,153.53
A.I.M.E.	12,222.47	6,008.38	3,308.00	1,903.00	23,441.85
Nonmembers	15,168.53	2,703.47	212.67	276.50	18,361.17
Total	$109,803.60	$52,898.24	$23,254.48	$14,566.75	$200,523.07

TABLE 4 NUMBER OF CONTRIBUTORS

Society	(1)	(2)	(3)	(4)	Percentage of total contributors (1)	(2)	(3)	(4)
A.S.C.E.	787	362	149	147	22.5	20.9	20.7	24.8
A.S.M.E.	1115	482	190	179	31.8	27.9	26.5	30.2
A.I.E.E.	1134	649	282	188	32.4	37.7	39.3	31.6
A.I.M.E.	265	134	86	68	7.6	7.8	12.0	11.4
Nonmembers	202	97	11	12	5.7	5.7	1.5	2.0
Total	3503	1724	718	594	100.0	100.0	100.0	100.0

TABLE 5 AVERAGE AMOUNT PER CONTRIBUTOR

Society	(1)	(2)	(3)	(4)
A.S.C.E.	$43.90	$49.14	$45.51	$34.03
A.S.M.E.	22.67	25.37	36.86	21.97
A.I.E.E.	19.84	22.16	21.09	18.36
A.I.M.E.	46.12	44.82	38.47	27.98
Nonmembers	75.09	27.94	19.33	22.54
Average	$31.32	$30.63	$32.39	$24.51

in the way of cash loans to meet urgent requirements. Major loans, not to exceed $25 in amount, are made with the understanding that the loan is to be repaid when the borrower is financially able to do so. No major loan is made without thorough investigation and approval by the Loan Committee. During the last year, major loans amounted to $311. The total outstanding major loans at the close of the year amounted to $15,315.50, with repayments totaling $1668, from 84 persons. In order to care for urgent needs requiring small outlay, the Social Service Department has authority to grant minor emergency loans, which are restricted to $3 for nonmembers and to $5 for members, the recipients not being pledged to repayment. During the year, minor emergency loans totaled $370.60. Total minor emergency loans outstanding amount to $4848, with repayments amounting to $153 from 17 persons.

SOCIAL SERVICE

No report of the operations of P.E.C.U. would be complete without special mention of the humanitarian work of the Social Service Department. The continued and active interest of Mrs. Josephine M. Barron, chairman, and Mrs. Samuel H. Dolbear, secretary, of the Social Service Department, the Women's Auxiliaries of the A.I.M.E. and A.S.M.E., and the Engineering Woman's Club, have enabled the P.E.C.U. to render a service to many that could not otherwise have been possible.

During the year, 149 cases were investigated of which aid was furnished to 120. Food orders were issued to 83 families, benefiting 680 persons, and in addition to this 85 Macfadden food books were issued to individuals.

Through arrangement with Commissioner Hodson's office, the Social Service Department was instrumental in aiding 66 families to be placed on home relief immediately, thus making for prompt eligibility for work relief. P.E.C.U. has also received donations of clothing of all kinds and from its clothing department 178 requests for apparel were filled. To date, a total of 600 men, 160 women, and 146 children have been aided in this respect. Through the courtesy of the Women's Auxiliary of the A.I.M.E. and the Engineering Woman's Club, 68 children were outfitted with new clothing at a cost of $335 and 43 Christmas packages were donated by the Engineering Woman's Club, aided by the Women's Auxiliary of the A.S.M.E.

Medical aid was furnished to 31 cases and free hospitalization and surgical care was arranged for 11 others. In this work thanks are due to Dr. William Z. Jerome and Dr. Matthew Slate for their continued cooperation with the Social Service Department. During the year it devolved upon the Social Service Department to arrange for two funerals. In two other cases the service was instrumental in arranging through the State Department for the return of persons to their homes or to relatives. Four cases requiring emergency shelter were cared for. Twenty-seven pairs of shoes were issued to children from the fund established through the generosity of William Heyman, and four pairs of shoes were issued to men from the fund established through the generosity of Mrs. W. O. Borcherdt. The activities of the department also included 10 cases of free legal assistance.

Graphic Arts Technical Conference

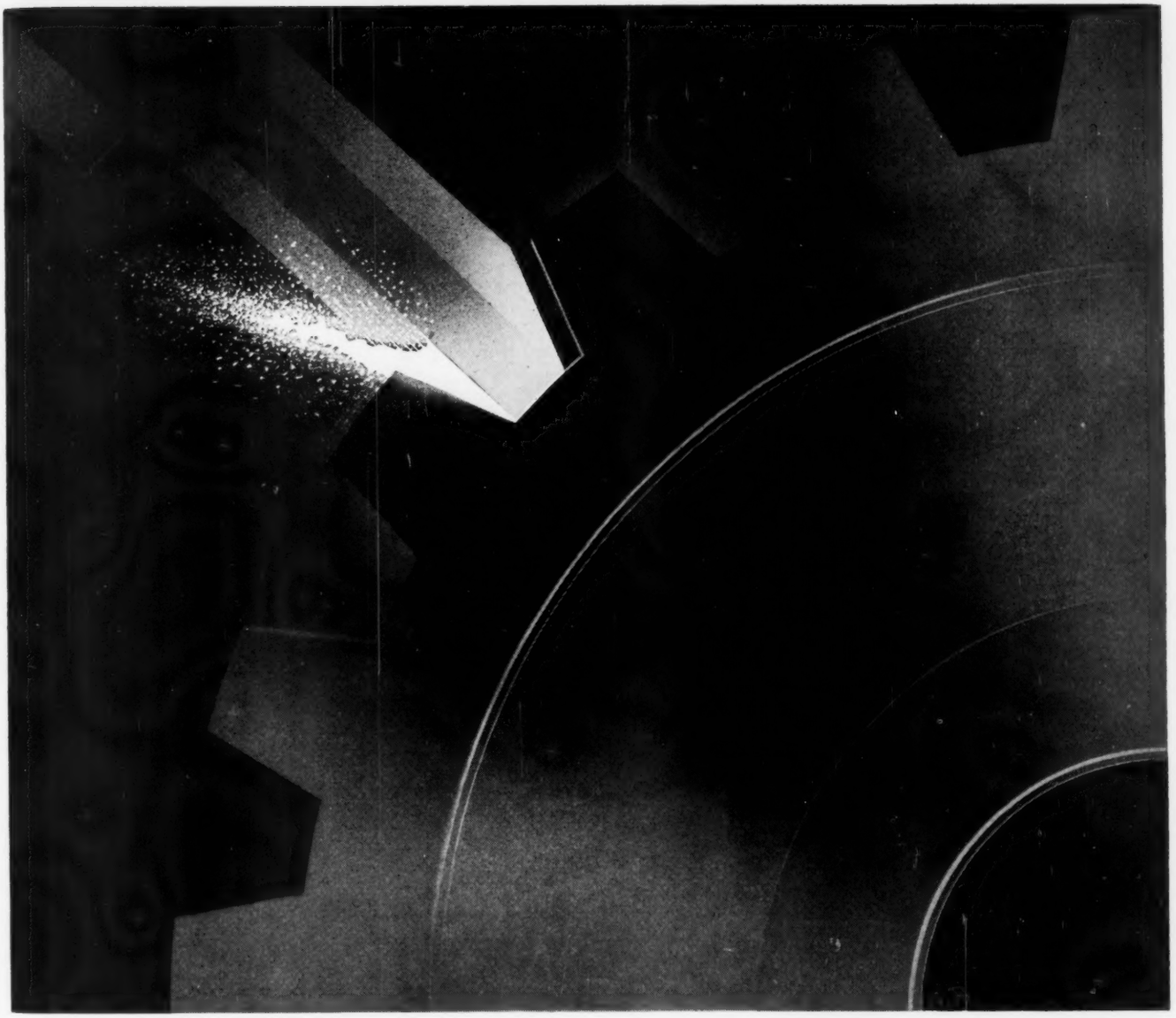
A GRAPHIC Arts Technical Conference will be held in Washington, D. C., on May 11 and 12, at the Wardman Park Hotel under the auspices of the Graphic Arts Research Bureau and in cooperation with the Graphic Arts Division of The American Society of Mechanical Engineers. The local arrangements are being guided by the Hon. A. E. Giegengack, Public Printer, and the technical program is being arranged by William C. Glass, W. G. Dodge, T. E. Dalton, E. P. Hulse, and Edward Epstean. The technical program will comprise four sessions, each of which will be a discussion conference. Problems of metals will be discussed at one session, at another, the relation of paper to printing, and at the third the application and evaluation of the three major printing processes. The final session of the conference will be a general technical discussion of problems and developments in inks, machinery and management, and photomechanics.

International Meeting, Naval Architects, Sept. 14–19

THE subject of safety of life at sea, which has grown in international importance during the past few years, will be the main topic of discussion when between 200 and 500 marine experts from all parts of the world convene in New York during the week of September 14 to 19, inclusive. This International Meeting of Naval Architects and Marine Engineers, the first to be held in this country, is being sponsored by the Society of Naval Architects and Marine Engineers, 29 West 39th Street, New York, and delegates from the foremost maritime technical societies of Great Britain, France, Italy, Germany, Japan, and this country will meet in technical sessions on September 15 and 16, at which time papers dealing with safety, transatlantic liners, and propulsion will be presented. While complete arrangements have not yet been made, it is expected that ten papers will be read and discussed.

Social events will be interspersed with the technical sessions and will be marked by a reception by Rear Admiral George H. Rock, president of the Society of Naval Architects and Marine Engineers, to be held on Monday, September 14, at the Webb Institute of Naval Architecture, New York City. Other social events will include a banquet to be held on September 15, a trip up the Hudson to West Point, New York, on September 17, a visit to Newport News, Va., where the Newport News Shipbuilding and Dry Dock Company, Mariners' Museum, Langley Field, Williamsburg, Jamestown, and Yorktown will be inspected on September 18, and a visit to Washington, D. C., on September 19. Arrangements are being made by a committee of which Captain Roger Williams, vice-president of the Newport News Shipbuilding and Dry Dock Company, Newport News, Va., is chairman.

(*Continued on page 274*)



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Contributors to Fund for the "Journal of Applied Mechanics"

THE *Journal of Applied Mechanics* has successfully completed its first year under the editorship of the Applied Mechanics Division of The American Society of Mechanical Engineers. The executive committee of the Division wishes to take this opportunity to thank all individuals, universities, and industries who ably assisted the *Journal* by their financial contributions during 1935, and to make public acknowledgment of this aid. A list of these various contributors for 1935 follows:

Universities and Colleges: Massachusetts Institute of Technology; Columbia University; University of Michigan; and University of Illinois.

Companies: E. I. du Pont de Nemours & Co., Westinghouse Electric & Manufacturing Co., Aluminum Company of America; and Hamburgische Schiffbau-Versuchsanstalt, Germany.

Individuals: J. B. Blood, R. P. Genereaux, E. H. Hagen, F. M. Lewis, R. E. Peterson, N. C. Riggs, A. M. Wahl, J. P. Den Hartog, J. N. Goodier, G. F. Jenks, A. Nadai, I. P. Robbins, G. F. Starbuck, M. M. Frocht, J. A. Goff, D. L. Holl, A. L. Kimball, K. E. Peiler, H. A. Rohrich, and S. Timoshenko.

Standards for Rotating Electrical Machinery Published

NEW and revised requirements for most of the rotating electrical machinery manufactured and used in the United States are now made available in a single volume, the "American Standards for Rotating Electrical Machinery," just published by the American Standards Association.

Standard requirements and specifications for electrical machinery, from the large central-station generators and industrial- and steel-mill motors to the small motors used on household appliances, such as vacuum cleaners and electric fans, are included in the new publication. Direct-current, synchronous, and induction machines, synchronous converters, and alternating- and direct-current fractional-horsepower motors are covered.

With new material added by the American Standards Association's committee, the publication combines revisions of the material formerly published by the American Institute of Electrical Engineers in five separate pamphlets (A.I.E.E. 5, 7, 8, 9, 10) and those motor and generator standards of the National Electrical Manufacturers Association which are of general interest.

The National Electrical Manufacturers Association rules which, with the American Institute of Electrical Engineers standards, form the basis for part of the new standards, deal particularly with manufacturing practice as it has grown up for various types of machines and include such standards as values for rating purposes, dimensions, and structural details.

The outstanding accomplishment of the standards of the American Institute of Electrical Engineers has been the definition of the terms and conditions which characterize rating and performance. The line of demarcation has not been distinct, and with the growth and increased detail of both the A.I.E.E. and N.E.M.A. standards, this dividing line became less distinct.

In the new standards, these two existing and overlapping sets of standards are combined to form one complete "common language" for rotating machinery.

Stevens Economic Camp June 28–July 5

THE Society for the Promotion of Engineering Education has accepted the invitation of Stevens Institute of Technology to hold a summer session on economics of engineering at the Stevens Engineering Camp, Johnsonburg, N. J., during the week beginning June 28. This will immediately follow the forty-fourth annual meeting of the Society at Madison, Wis.

A special S.P.E.E. committee to draw up the program of the session and to cooperate with representatives of Stevens in making all arrangements comprises: O. W. Eshbach, of the American Telephone & Telegraph Company, chairman; Walter Rautenstrauch, of Columbia University; Harvey N. Davis, of Stevens Institute of Technology; A. R. Cullimore of Newark College of Engineering; R. A. Seaton, of Kansas State College; E. L. Grant, of Stanford University; J. W. Roe, of New York University; Dexter S. Kimball, of Cornell University; H. P. Hammond, of Brooklyn Polytechnic Institute; and P. T. Norton, of Virginia Polytechnic Institute.

It is proposed to have two morning sessions and one evening session each day from June 28 until Sunday evening, July 5. Afternoons are to be reserved for recreation and for informal conferences and discussions. The day-by-day schedule will be announced later by the committee in charge. Those attending the sessions will be for the most part teachers of economics in engineering schools and colleges.

Summer schools for engineering teachers have been held by the Society for the Promotion of Engineering Education in different institutions throughout the country since the Society completed a general investigation of engineering education in 1929. The first summer school in economics of engineering was conducted with the cooperation of Stevens Institute of Technology on the college campus at Hoboken four years ago.

The Stevens Engineering Camp, where the summer school will be held, is in the hill country of northern New Jersey, about 60 miles from New York City, not much farther from Philadelphia, and within easy motoring distance of Trenton, Princeton, Easton, and Bethlehem. Railroad service is available to Johnsonburg on the main line of the Lackawanna Railroad. The camp tract of 375 acres, with a natural lake of 30 acres, was acquired by Stevens in 1929 and developed for undergraduate instruction in surveying. The permanent camp buildings include 18 dormitory cabins scattered through the woods on the shore of the lake, a dining hall, at one end of which is a lounge for evening conferences, the Bristol building in which are drafting, conference rooms and several class rooms, and various service buildings.

Lamme Medal Awarded to Vannevar Bush

THE 1935 Lamme Medal of the American Institute of Electrical Engineers has been awarded to Vannevar Bush, vice-president of the Massachusetts Institute of Technology, and Dean of the School of Engineering, and member, A.S.M.E., "for his development of methods and devices for application of mathematical analysis to problems of electrical engineering." The medal and certificate will be presented to him at the annual Summer Convention of the Institute, which is to be held in Pasadena, California, June 22–26, 1936.

The Lamme Medal was founded as a result of a bequest of the late Benjamin G. Lamme, chief engineer of the Westinghouse Electric & Manufacturing Company, who died on July 8, 1924, to provide for the award by the Institute of a gold medal (together with a bronze replica thereof) annually to a member of the American Institute of Electrical Engineers, "who has shown meritorious achievement in the development of electrical apparatus or machinery" and for the award of two such medals in some years if the accumulation from the funds warrants. A committee composed of nine members of the Institute awards the medal.

Coming Meetings of A.S.M.E. Local Sections

Boston: April 30. Engineers' Club, 2 Commonwealth Ave., Boston. Dinner at 6:30 p.m. Meeting at 7:30 p.m. Subject: Plastics, by Joseph B. Fuller, vice-president, Northern Industrial Chemical Co., Boston, Mass. Subject: Industrial Finishes, by Charles D. Harford, Arthur D. Little Co., Cambridge, Mass.

Florida: April 2, 3, and 4. Hotel Clarendon, Daytona Beach. Technical sessions, smoker, banquet, and national societies' dinners will all be held at this hotel. The A.S.M.E. Florida Section is sponsoring the second session of the meeting on Thursday, April 2, at 2:30 p.m.

Metropolitan: April 2. Engineering Societies Building, 29 West 39 St., New York, N. Y. Subject: Air Conditioning.

April 2. Auditorium, Engineering Societies Building, at 7:30 p.m. Subjects: Modern Trends in Air Conditioning, by W. L. Fleisher, consulting engineer, New York City; Air-Conditioning Methods, by John Everetts, Jr., Air and Refrigeration Corporation, New York City; The Place of Ice in Air Conditioning, by C. F. Holske, American Ice Co., New York City; Central Station Vs. Unit Systems, by A. E. Stacey, Jr., Buensod-Stacey Corporation, New York City; The Architect Views

(*Continued on page 276*)

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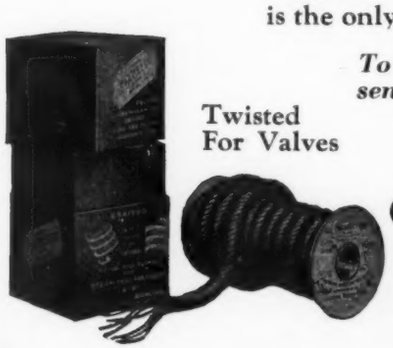

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Air Conditioning, by Francis Keally, architect, New York City.

April 8. Engineering Societies Building, at 8:00 p.m. Subject: The Reynolds Number, by Prof. Boris A. Bakhmeteff, Columbia University.

April 9. Room 1101, Engineering Societies Building, at 8:00 p.m. Subject: Flash Drying of Waste Residues, by Richard F. O'Mara, Raymond Brothers Impact Pulverizer Co., Chicago, Ill.

April 9. Engineering Societies Building, at 7:30 p.m. Subject: Communication and National Defense—The Role of the Signal Reserve, by Capt. Henry C. Anderson, 302nd Signal Battalion.

April 9. Engineering Societies Building. Meeting to be sponsored by the Process Industries Division of the A.S.M.E.

April 21. Roger Smith Restaurant, 40 East 41 St., New York, N. Y., at 7 p.m. President William L. Batt will address the members on "Unity of the Profession" and a testimonial will be presented to Mr. Eric Oberg in recognition of his service as treasurer of the Society from 1925 to 1935.

April 27. Room 502, Engineering Societies Building, at 7:30 p.m. Subjects: Application of Aerodynamics to Railroads, by Prof. Alexander Klemin, New York University; How Railroads Are Receiving the Application of Aerodynamics, by L. K. Sillcox of the New York Air Brake Co., New York, N. Y.

April 30. Engineering Societies Building, at 7:30 p.m. Subject: The Gradual Development of Small Arms and Ammunition From Early to Present Times, by Captain Phillip Houghton, Ordinance Reserve.

New Haven: April 8. Mason Laboratory, Sheffield Scientific School, New Haven, Conn., at 8:00 p.m. Subject: Chemistry, by Clifford C. Furnas, Associate Professor of Chemical Engineering, Yale University.

April 15. Mason Laboratory, Sheffield Scientific School, New Haven, Conn., at 8:00 p.m. Subject: Astronomy, by Dirk Brouwer, Assistant Professor of Astronomy, Yale University.

Ontario: April 9. Room C-22, Mining Building, University of Toronto at 8:00 p.m. Subject: The Mechanical Engineer and His Place in Modern Business Practice, by E. C. Weisberber, engineer, Master Separator & Valve Co., Toronto, Ont., Can.

Philadelphia: April 28. Engineers' Club at 8:00 p.m. Subject: Modern Home from an Engineering Standpoint, by Morrison Blake, Philadelphia Electric Company, Philadelphia, Pa.

Schenectady: April 2. Rice Hall, Schenectady, N. Y., at 8:00 p.m. Subject: A.I.E.E.—A.S.M.E. Competition.

A.S.H.V.E. Officers

AT THE 42nd annual meeting of the American Society of Heating and Ventilating Engineers the following officers were elected: President, G. L. Larson, Madison, Wis.; first vice-president, D. S. Boyden, Boston, Mass.; second vice-president, E. H. Gurney, Toronto, Canada; treasurer, A. J. Offner, New York, N. Y.; council (three years), R. C. Bolsinger, Norristown, Pa.; S. H. Downs, Kalamazoo, Mich.; W. L. Fleisher, New York, N. Y.; C. M. Humphreys, Pittsburgh, Pa.; (two years), Albert Buenger, St. Paul, Minn.; F. E. Giesecke, College Station, Texas; J. F. McIntire, Detroit, Mich.; W. E. Stark, Cleveland, Ohio; (one year), M. C. Beman, Buffalo, N. Y.; L. Walter Moon, St. Louis, Mo.; John Howatt, Chicago, Ill.; O. W. Ott, Los Angeles, Calif.; and W. A. Russell, Kansas City, Mo. Messrs. Larson, Humphreys, Downs, McIntire, and Stark are members of The American Society of Mechanical Engineers.

Candidates for Membership in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after April 27, 1936, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member having comments or objections should write to the secretary of the A.S.M.E. at once.

NEW APPLICATIONS

APPLEGATE, WM. A., N. Plainfield, N. J. (Rt)
BERRY, ROBLEY E., Berkeley, Calif.
BRAILO, GEORGE P., Brooklyn, N. Y.
BRAUN, JOHN J., Norwood, Ohio
BUSHNELL, LESTER P., Naugatuck, Conn.
CLARK, JAMES D., Hampton, Va.
COLE, PAUL W., Danville, Pa.
CONTA, LEWIS D., Rochester, N. Y.
COOPER, BENJAMIN, New York, N. Y.
DAASCH, FRANCIS J., Muscatine, Iowa
DANIELS, DANIEL V., Brooklyn, N. Y.
DEAN, SIDNEY, Peru, Ill. (Re)
DOUGHERTY, WILLIAM F., JR., Brooklyn, N. Y.
DYER, WESLEY B., New York, N. Y.
GREEN, ANDREW S., Berkeley, Calif.
HEITZ, RAYMOND E., Brooklyn, N. Y.
INGLES, JOHN S., Paducah, Ky.
KOPP, SIGMUND, Jersey City, N. J.
LAUGHTON, WATSON B., Philadelphia, Pa.
MABLEY, THOMPSON, H., Detroit, Mich.
MASCOTT, LUIS, Mexico, D. F.
McCARTY, ROY A., Wilkinsburg, Pa.
MERCNER, R. O., New York, N. Y. (Rt & T)
MITCHELL, W. F., Canton, N. C.
MOORE, WESLEY R., Atlanta, Ga.
MULLEN, T. J., JR., Washington, D. C.
NAYLOR, JAMES W., Niagara Falls, N. Y. (Rt)
PETERS, A. HAROLD, Manhasset, N. Y. (Rt)
PLATOU, LEIV S., Southington, Conn.
RIPLEY, F. D., Keystone, W. Va.
RUESS, MAX EMIL, Milwaukee, Wis.
SCHMITT, B. A., Brooklyn, N. Y. (Rt)
SHEA, FRANCIS X., Jamaica, L. I., N. Y.
SHOEMAKER, R. W., Woodbury, Conn.
SHURAVLEV, ALEXANDER J., San Francisco, Calif.
SMITH, GERARD L., York, Pa.
SPENCER, ROBT. D., Kansas City, Mo. (Re)
STEPHENS, GORDON A., Long Branch, Ont., Can.
TROGER, GEORGE F., New York, N. Y.
TURNER, WILLIAM P., Norwood, Pa.
WESTPHAL, ALBERT H., Detroit, Mich.
WILLITS, C. W., Saginaw, Mich. (Rt & T)

CHANGE OF GRADING

Transfers from Member

BROOKS, PROF. MORGAN, Urbana, Ill.
HULSE, GEO. E., New Haven, Conn.
LAWRENCE, HOWARD B., New York, N. Y.

Transfers from Junior

ARNOLD, CHARLES B., Hempstead, L. I., N. Y.
FISCH, JACOB, York, Pa.
MARTIN, HENRY B., York, Pa.
OESTERLE, PAUL D., Philadelphia, Pa.
O'NEIL, ROBERT D., Birmingham, Ala.
SANDERS, JOHN, San Francisco, Calif.
SCOTT, ROGER M., Providence, R. I.
WEISS, JOSEPH R., New York, N. Y.
WHITAKER, U. A., Canton, Ohio

Necrology

THE following deaths of members have recently been reported to the Office of the Society:

BOYD, FRANK F., February 11, 1936
BRIGGS, HENRY C., January 21, 1936
CHINN, JOHN W., February 7, 1936
CLOUD, JOHN WILLS, January 14, 1936
GREEN, JAMES B., November 8, 1935
MILLER, JESSE F., January 28, 1936
PAGE, JULIAN D., February 3, 1936
PONISOVSKY, JAMES M., December 31, 1935
PURVES, JOHN B., February 19, 1936
RICHARDS, CHARLES RUSSELL, February 21, 1936
SKEEN, DAWSON H., February 23, 1936
SMITH, WARREN P., February 3, 1936

A.S.M.E. Transactions for March, 1936

THE March, 1936, issue of the Transactions of the A.S.M.E., the *Journal of Applied Mechanics*, contains the following papers:

TECHNICAL PAPERS

Design Aspect of Creep, by R. W. Bailey
The Creep of Metals—II, by A. Nadai and E. A. Davis
Two- and Three-Dimensional Cases of Stress Concentration, and Comparison With Fatigue Tests, by R. E. Peterson and A. M. Wahl
The Rate of Growth of Fatigue Cracks, by A. V. deForest

RESEARCH REVIEWS

Recent Research in Elasticity, by J. N. Goodier

DESIGN DATA

Stress and Deflection of Circular Plates, by A. M. Wahl and Stewart Way

DISCUSSION

On previously published papers by J. P. Den Hartog and J. G. McGivern; M. Stone; W. E. Johnson; and C. R. Soderberg

BOOK REVIEWS

By J. C. Hunsaker; J. P. Den Hartog; L. C. Maugh; S. Timoshenko; J. Ormondroyd; and J. A. Goff

For closing dates on discussion, see footnote on first page of each paper.